VOL. XXVIII. — No. 1. JANUARY 1951

Monthly Bulletin of the International Railway Congress Association

(English Edition)

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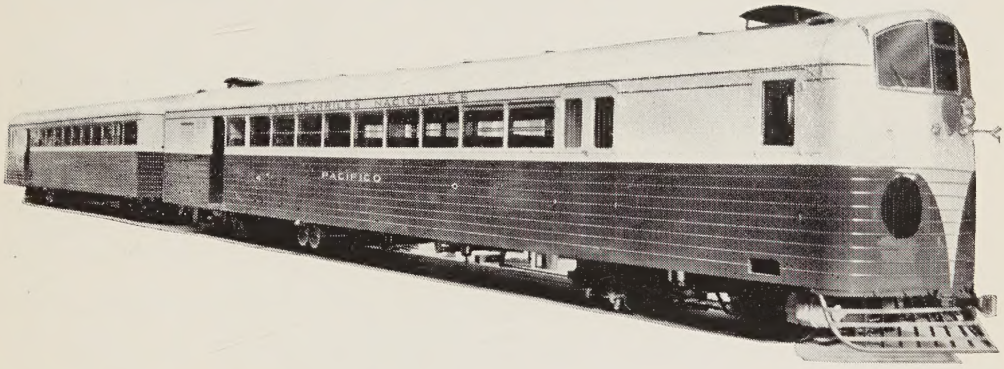

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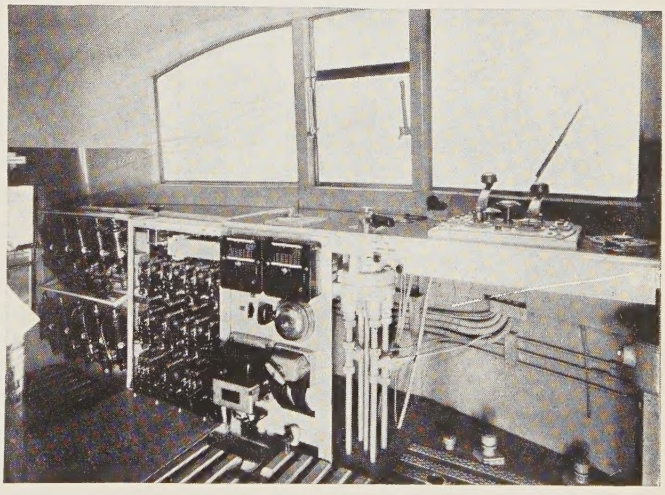

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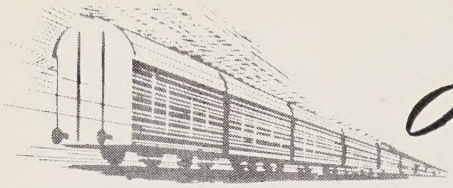

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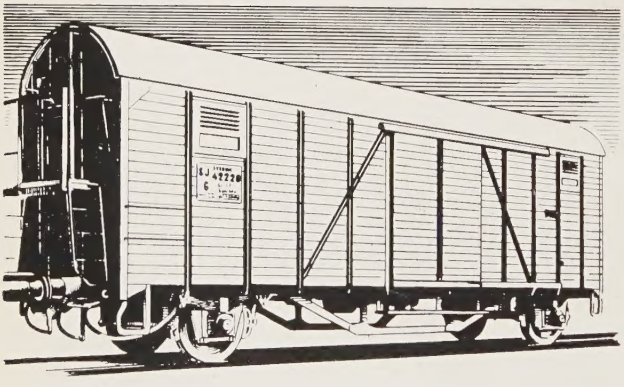

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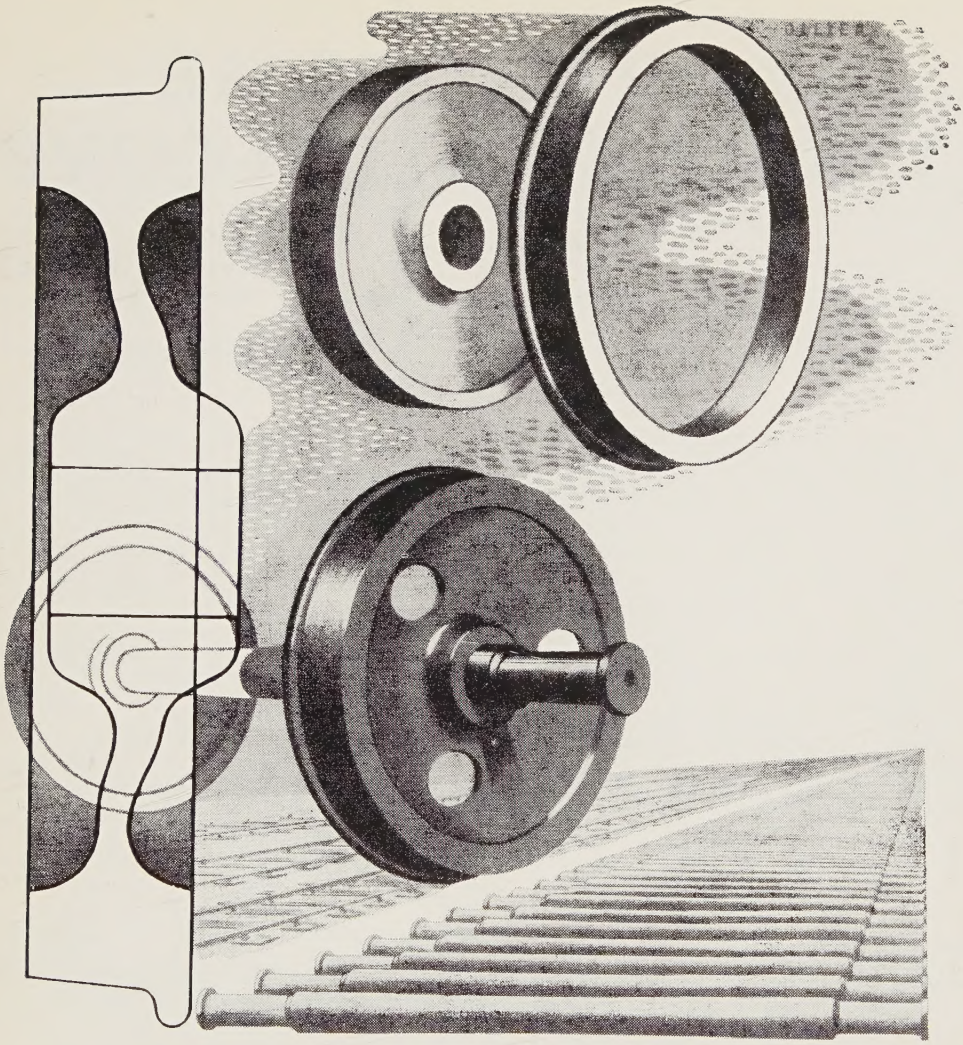

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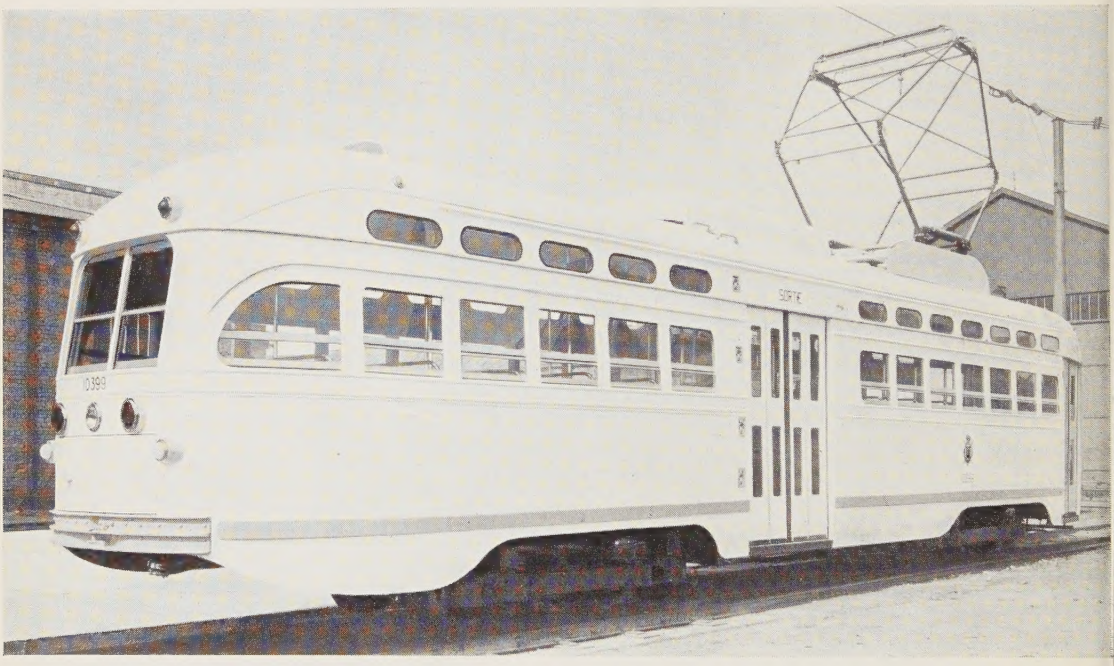

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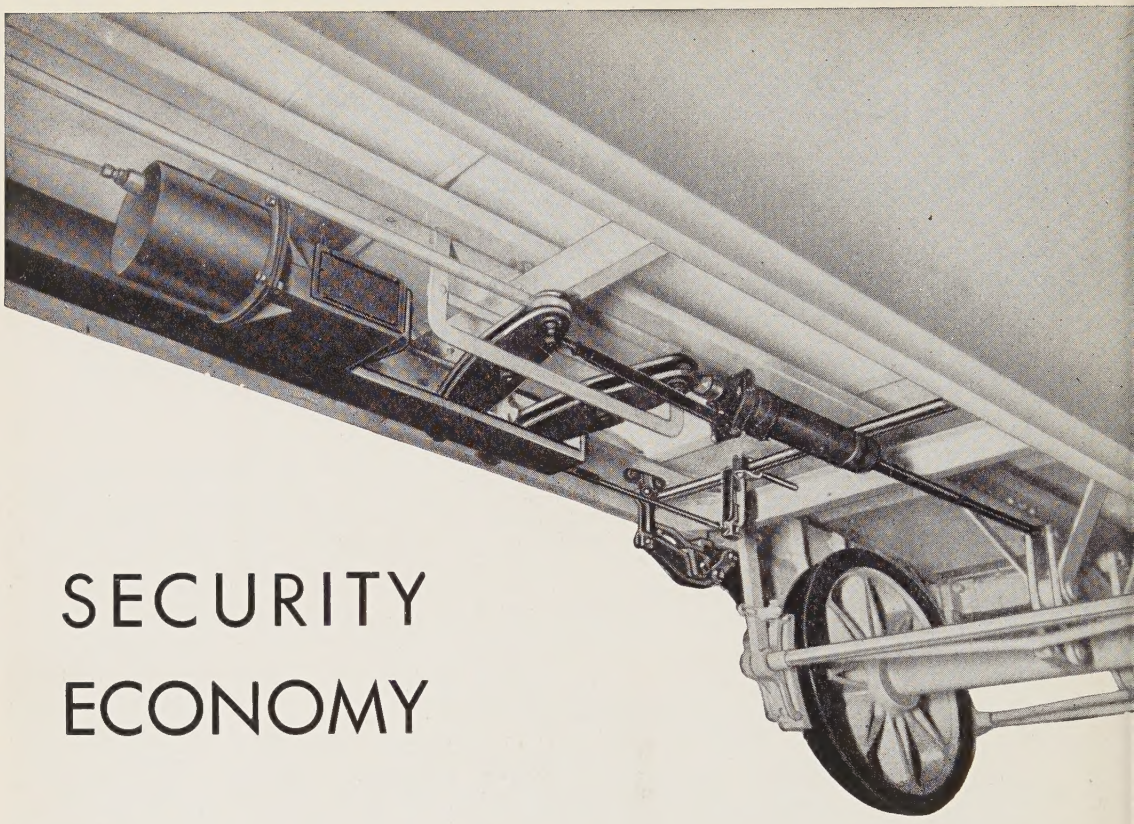

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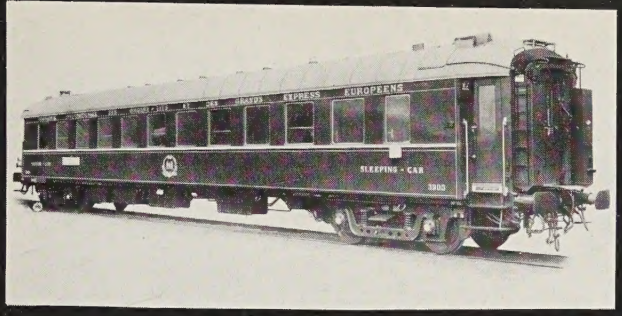

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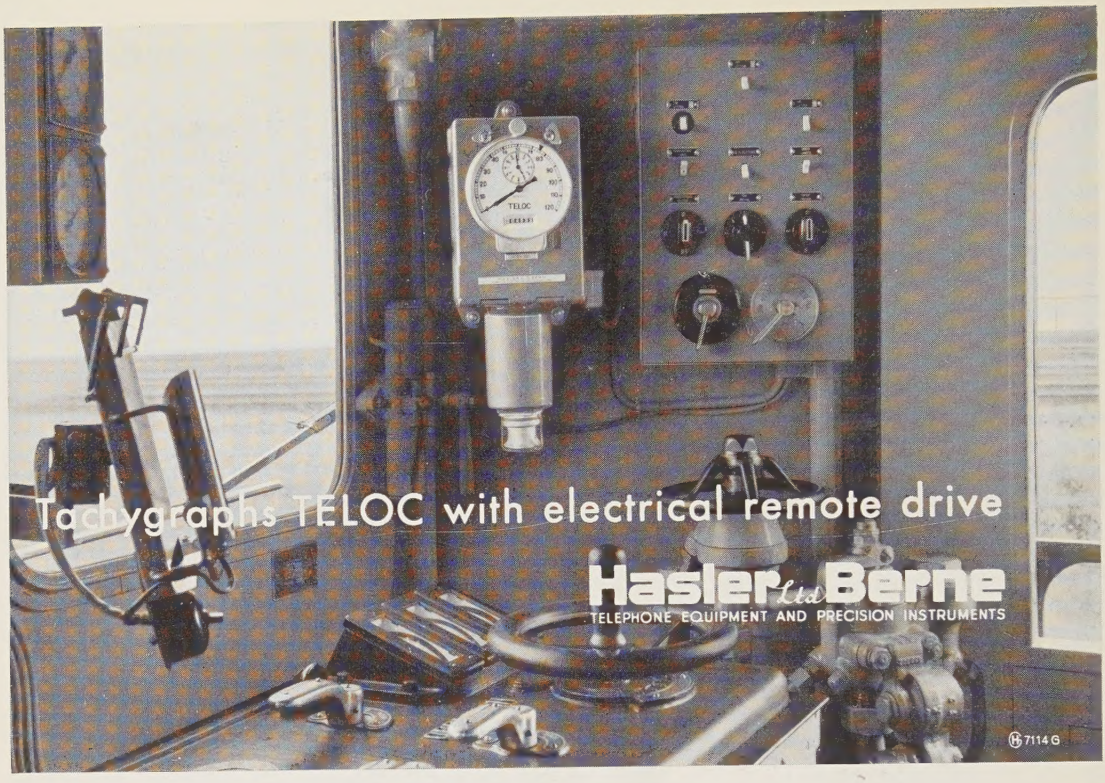
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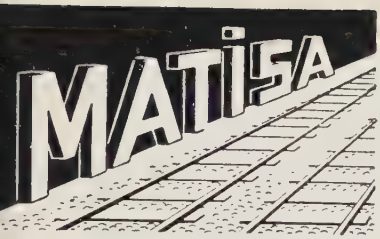

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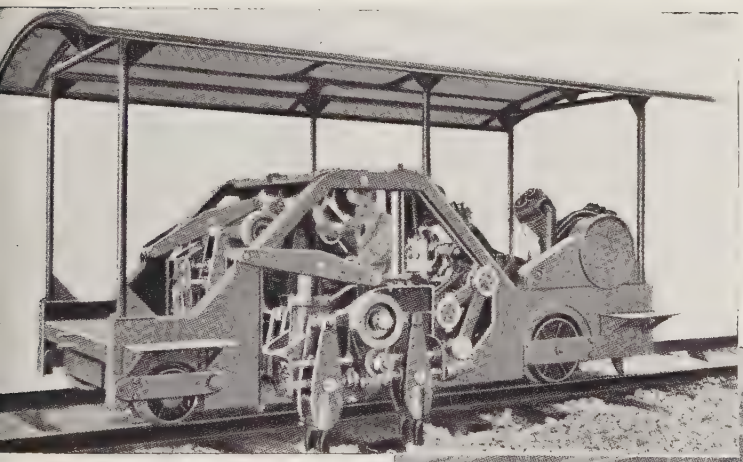

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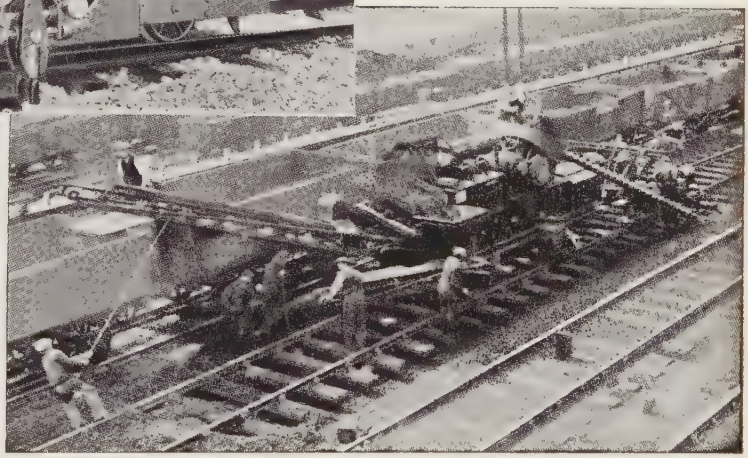

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MONTHLY BULLETIN

OF THE

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(ENGLISH EDITION)

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An edition in French is also published.

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BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[625 .143 .2 (493)]

The problem arising from the use of basic Thomas steel rails on the system of the Belgian National Railways,

by J. SERVAIS,

Inspecteur technique principal honoraire de la Société Nationale des Chemins de fer belges.

In 1924 and 1929 (1), when the Belgian National Railways introduced new technical conditions for the supply of rails, we examined and commented on the reasons which justified the arrangements which were introduced for improving the quality of the rails and we tackled the subject at this period since all the principal networks were noticeably and constantly preoccupied with the problem, whether they used Siemens-Martin, Bessemer acid or Bessemer basic (Thomas) steel rails, according to the varying conditions of supply of the necessary metals or the vicinity of phosphorous ores.

In effect the components of the track, and more especially the rails themselves, which have to resist direct contact with the tyres carrying the live loads, introduce complex problems on which depend the safety of the trains while they constitute at the same time a most important factor in the economic operation of the railways.

Thus in 1938 and 1949, which years we quote as examples, the outlay on track material (rails, fastenings, fishplates, soleplates, ballast and sleepers) amounted respectively to 126 917 000 frs. and 658 967 000 fr.

Rails alone amounted in these totals to 28 078 858 frs. and 283 552 729 frs., say 22.1 % and 43 %.

Having examined the results obtained with rails of basic (Thomas) steel since 1893, the date when the process was introduced in general practice in Belgium, we expressed the opinion that it was possible to manufacture good rails in basic Thomas steel of a quality equal to those produced under the other processes. It should be understood that these comparisons must be referred to careful manufacture, both as regards preparation of the metal as well as the rolling and finishing of same.

(1) *Bull. of the Int. Ry. Congress Association* for July-October 1925 and June 1930.

25 years having elapsed since we expressed the above opinion, it appeared to us to be a matter of interest to determine the situation at the present time on the S. N. C. B. (*) system.

We should remember first of all that the 50 kg/m section was until 1925 reserved to main lines and since that date had been put into general use. At present about 75 % of the main lines carry this section.

Since 1931, the length of the rails, which hitherto had not exceeded 18 m (59′ 5/8″) has been raised to 27 m (88′ 7″) for all main lines and, since 1935, the heat treatment of the extremities has been applied to all rails of this length in order to ensure, by increased hardening that the fished joints will stand up better.

We shall return to this question later on.

For tracks provided with 27 m rails, the sleeper spacing amounts to 41 sleepers.

In the Brussels-Antwerp electric line, the greater part has 54 m (177′ 2″) rails made up of 2-27 m rails welded together electrically by butt welding.

These rails are supported by 82 sleepers, provided with ribbed-soleplates, the rail being fixed by means of clips and bolts. The same arrangement is applied to a certain number of rails of the newly electrified Brussels-Charleroi line.

According to a recent decision, the installation of 54 m rails will be progressively introduced on all the most important lines in the country. In this way the number of joints will be reduced to a third of the number of joints of tracks having 18 m rails (1).

For the existing tracks using 18 or 27 m rails, these will be bedded on wooden sleepers, at 1/20th. However on curves of less than 600 to 1 000 m (1968′ 6″ to 3280′ 10″) radius, according to the importance of the lines, the sleepers are fitted with steel ribbed-soleplates.

For many years the size of gap in the joints of rails secured by fishplates, was based on the simple formula for linear expansion.

On this account the lengths of the rails were limited at first to 9 m (29′ 6″) then to 18 m and later to 27 m.

The gaps in the joints, calculated in this way would have been excessive for still longer rails and would have increased the percussion to an inadmissible extent.

Welding the rails together having made it possible to obtain rails of considerable length, it was found by observation that the gaps left when the rails are laid, could be less than those calculated for the widest gaps according to free expansion due to temperatures of the season.

Nowadays, it is admitted that no matter how the track is laid, expansion is more or less affected by the tightening up of the bolts holding down the rails onto the sleepers, by the tightening of

(*) In the present article : « S. N. C. B. » stands for Société Nationale des Chemins de fer belges.

(1) In the tunnels, rails of 108 m (354′ 4″) length are laid, by welding together four 27 m rails.

the fishplate bolts and by the pressure of the ballast.

When the holding power of rail attachments is considerable, as is the case when the rails are held by clips and bolts, the resistance to creeping, offered by the ballast, comes into play.

Hence variations in temperature always tend to produce more or less important stresses in the rails (either compressive or tensile). These stresses increase from the ends of the rails towards their midpoints, so much so that for rails of very great length, expansion of the middle parts of the rail is entirely suppressed by opposing forces. Only the extremities of the rail are subject to expansion.

It is possible to determine the value of tensile and compression stresses which may result; but the phenomena are complicated by the fact that an accurate analysis is impossible.

To recall here the calculations would be outside the scope of the present article.

What makes the exact calculation particularly difficult if not impossible, is that the position at any given instant, depends on all the expansions or contractions to which the rail has been subjected previously. It is only at the highest and the lowest temperature that the length of the rail has a fixed value independent of the variations of preceding temperatures. This state of affairs is again interfered with by the shocks and vibrations due to the passage of the trains. But these disturbances cannot, to any great extent, affect the basic theory of the stresses.

The experiments on the Belgian network had enabled us to estimate that under certain circumstances, stresses of the order of 6 kg/mm² (3.809 t. per sq. inch) can arise (1).

Moreover, it is worth noting that short rails may likewise, owing to closing of a certain number of joints, due to creepage, exhibit stresses of the same intensity as the very long rails referred to above.

This is why, taking the foregoing considerations into account and also results of experiments, certain networks, including the S. N. C. B., consider that nowadays it is possible to make a practice without risk, of using long rails (50 to 60 m.) (164′ to 196′) with reduced gap openings.

As regards welding, the static and dynamic tests which were carried out, justify the conclusion that electrical resistance welding, followed by normalization by heat treatment in a furnace or by a ring winding carrying high frequency current, has undoubted superiority compared to the other methods as it ensures security for the life of a rail placed in a track subject to high stresses (2). These welds must be made *at the central track workshops* where fixed welding machines are installed.

In the marshalling yard tracks and other accessory sidings in existence, the S. N. C. B. uses thermit welding (intercalary fusion welding) *carried out in situ*

(1) See *Bulletin of the International Railway Congress Association* of January 1937, Report by M. Ch. LEMAIRE, Director of the Permanent Way of the S. N. C. B.

(2) See *Bulletin of the International Railway Congress Association* of January 1938. « The welding of rails on the S. N. C. B. », by E. DESORGHER, Chief Engineer.

for building up sections of some hundred metres in order to avoid the use of fished joints as far as possible, since maintenance of the latter is very heavy.

As regards the working conditions, we do not think it is necessary to emphasize the fact that the Belgian network is the most crowded one in the world with *7 850 km* (4 880 miles) *of main lines and 5 345 km* (3 320 miles) *of accessory lines,* or a total of 13 195 km (8 200 miles) of track spread over 30 000 km² (11 590 sq. miles) of country, including many congested industrial centres.

The following table gives the densities of *passenger* traffic for the years 1913, 1926, 1938 and 1949.

Year	Daily number of trains	Kilometres covered for the year
1913	3321	46 600 000 (1)
1926	2413	39 000 000 (1)
1938	4042	62 000 000 (1)
1949	3400	49 585 000

Table for *goods traffic,* is as follows :

Year	Daily number of trains	Kilometre-tons carried
1913	2571	5 290 000 000
1938	1340	5 143 000 000
1949	1838	5 666 000 000

(1) The statistics do not include the traffic of the Compagnie du Nord Belge, which was only taken over by the S. N. C. B. in 1940.

The increase in power of the locomotives and the study of the routing made it possible, as will be seen, to cut down the number of trains far below that of 1913 for the movement of a tonnage that was if anything greater than before.

The combined gross kilometre-tons of *passenger* and *goods* trains give us the figures shown below :

Year	Kilometre-tons carried (gross)
1929	32 016 000 000
1938	25 999 000 000
1949	25 265 000 000

The speed of trains was likewise substantially increased.

In 1926, it took over 2 hours to do the trip Brussels-Ostend, i. e. 121 km.

In 1938, the same run took normally 1 hr. 15 min. Certain expresses reached a speed of 140 km on the stretch between Ghent and Bruges and the Brussels-Ostend trip was done in the hour.

In 1926 it took 2 hr. 10 min. to get from Brussels to Liége (100 km); in 1938, only 1 hr. 15 min.

To be quite accurate, it must be stated that since the liberation (1944), it has not been possible to recover these speeds due to the effects of the war and particularly to the state of the tracks of which maintenance and renewal were considerably delayed.

We may note in passing that the road signals give sufficiently accurate informa-

tion to enable trains to be run at speeds up to 150 km/hr in perfect safety.

For goods trains, the maximum authorised speed up to 1926 was 45 km/hr on the best lines.

Equipment of the trains with compressed air brakes enabled this speed to be raised to 60 km/hr and for certain postal services, for carriage of perishable goods or to meet requirements in international relations even up to 85 km/hr.

During the same period, axle loads were increased and the most highly loaded Belgian axles to-day are those carrying 24 tons on the Pacific type locos and those of certain special goods waggons carrying 20 tons per axle.

The engineering developments in transport and particularly the increase in live loads and in speeds have thus introduced an important increase in the static and dynamic stresses in the track and specially in the rails.

In order to obtain the performances mentioned above, it has been necessary to study systematically the lay-out of the tracks and to organize methodically the maintenance service and the renewal by use of suitable modern machine tools (1).

In short, if we take into account, in addition to the data summarized above, the short distances between stations, the great sinuosity of the lines, the gradients in longitudinal section which are so irregular, the large number of crossings and signals, which tend to increase the areas where braking takes place and the possible cause of skidding and of pivoting of the axles of the motors, it is no exaggeration to arrive at the conclusion that the present conditions of operation on the S. N. C. B., form an exceptionally severe fatigue test for the rails.

And incidentally, it is the rails of basic (Thomas) steel which have got to meet these requirements.

Moreover, Belgium is not the only country that uses this steel for its rails. Other important networks such as the French National Railways, with its highly developed network and high speed services; Switzerland with its numerous mountain railways; Holland, and Denmark use basic Thomas steel rails.

The French National Railways, who have been able to compare over a period of many years, the merits of basic Thomas steel rails and of Siemens-Martin steel, are of opinion that the former are at least equal in quality to the last-mentioned product. In proof of this the said railways now use basic (Thomas) steel exclusively (1).

In Germany, manufacture of rails from the Thomas converter was by a long way ahead of that using Siemens-Martin steel in the period preceding the last war, and if at the present time, the latter process appears for the time being to be in the ascendant, it is not on account of a defect in quality of the Thomas rail, but purely owing to the force of circumstances arising from the war.

(1) In this connection we would refer to the well-supported research by M. R. CAMPUS, Honorary Chief Engineer of the S. N. C. B., entitled « La réalisation d'une voie ferrée de qualité », 1946. Ed. Hayez, rue de Louvain, 112, Brussels.

(1) In this connection see the note by M. PALMÉ, Engineer, Chief of the Subdivision « Rails », of the French National Railways, entitled « Basic Thomas steel rails on the S. N. C. F. », published in the *Revue Générale des Chemins de fer*, for December 1949.

In addition, we can state that the Thomas steel works have, during the last years, made progress to the same extent as the Martin steel works and that they are still busy studying possible improvements (1).

Clearly, the production of gradations of hardness in the Thomas converter calls for well known precautions :

1) Raw materials of prime quality.

2) Use of physically hot smelts, regular and with low sulphur content.

3) Lime pure and well burnt.

4) Scrap of good quality.

The article, published in 1925, by Dr. Ing. CANARIS, of Hamborn, dealing with the use of Basic Thomas steel in the manufacture of rails, meets the objection so frequently quoted, namely that it is impossible to reduce the phosphorous content in the Thomas steel for rails so that it will no longer be harmful, with the following remarks :

« The metallurgist has long since overcome this difficulty. By a suitably graded addition of lime and scrap as a cooler, and during the blow of the converter, the temperature is kept low enough to attain a very high degree of dephosphorization.

« After removing the slag as completely as possible, the remaining slag is so completely saturated with lime that the greater part of the fused metal can be poured into the ladle without any slag being carried over; as a result the rephosphorization is very small. »

Further on he adds on the question of removal of gas :

« As regards the low temperatures of the melt which favour dephosphorization, we have noted that the temperature at which the ladle is filled is about 1 590°, whereas for mild steel it is higher by about 60°.

« By maintaining a relatively low temperature one also avoids the danger, often mentioned by the adversaries of the Thomas process of a too great absorption of gas by the melt, since this depends in the first place, according to more recent research, on the temperature. »

As regards oxidation phenomena, M. J. WAGNER, Chief Research Engineer at the S. A. des Aciéries Réunies de Burbach, Eich, Dudelange (A.R.B.E.D.) summarized in 1929 his « Comparative Study of the oxidation and deoxidation phenomena in the manufacture of rails by the Thomas and by the Siemens-Martin processes » in the following terms :

« The formation of FeO during the blow and the overblow is neither accidental nor harmful; it is a phenomenon that is produced intentionally and is necessary for the rapid accomplishment of the refining process by oxidation, which if it has to be effected by direct combustion alone of the impurities by gaseous oxygen, calls for so large a volume of air that the bath will solidify

(1) We would point out that the « Centre National Belge de Recherches Métallurgiques (C. N. R. M.)», instituted under the aegis of the important National industry and the specialized schools of the Universities, aims at perfecting the technique and improvement of the products of the metallurgical industry. In particular it has since several years been actively engaged in examining the possible improvements in the manufacture of basic steel (Thomas).

due to cooling off in the course of the operation.

« If there is no oxygen present in the form of FeO in the bath the surfaces of reaction would be restricted to the surfaces of air jets passing through the bath of molten metal. The weight of air passing through the bath and the heat carried away by the nitrogen, must therefore be incomparably greater. »

And M. WAGNER continues :

« This same condition of oxidation of the refining bath is required in the Siemens-Martin process, in which iron ore or scale from the rolling mill provides the necessary FeO for the reactions.

« The proof that the FeO only serves as a vehicle is shown in a striking manner by the contents in oxygen before and after the most violent and most unjustly feared phase, namely the overblow.

The values found at the time of our experiments are respectively 0.106 % and 0.095 %.

« Thus there is no increase but actually a decrease because the growing appetite of the phosphorus for oxygen destroys the FeO more quickly than it can be replaced by the blast.

« Since superoxidation is impossible, the final deoxydation by liquid additions will be just as efficacious and complete as that obtained in the Siemens-Martin process. »

* * *

The supervision by the agents of the S. N. C. B. covers all stages of manufacture.

The instructions contained in the Specification, of which the latest edition is dated 1948, enable one to recognize the nature, the diversity and the relatively large number of controls in operation.

The proportion of tests is based on the number of casts and of ingots. The weight of the casts varies from 15 to 30 tons according to the capacity of the converters and the state of wear of the dolomitic lining.

These tappings provide from 3 to 6 ingots of 4 000 to 4 200 kg in weight.

Tapping into ingots is made by allowing the metal to fall freely, under appropriate conditions as regards output and temperature and regularly controlled, tending to bring about solidification of the steel as rapidly as possible.

The ingot moulds used must be new or freshly reconditioned and suitably coated or lacquered, in order to prevent any hindrance to the rise of the metal in the mould and thus to eliminate the risk of cracks and defects on the surface of the ingots.

After waiting a minimum of 20 minutes at the feed box, the solidification of the ingot will be sufficiently far advanced to permit of its being stripped from the mould. The ingots are then taken to the pits where they remain for as long as is necessary for uniform cooling before delivering them to the furnaces and thence to the rolling mills. The time of their sojourn in the pits as well as the temperature maintained in the latter, are two factors of major importance in order to secure a satisfactory degree of homogeneous mild steel.

It should be noted that this period of maintenance at high temperature favours

the diffusion of carbon in the solidified metal and tends to uniform composition of the whole section.

The ingots are then set aside successively and passed to the blooming mill where they are transformed by numerous passes by graduated pressures on the 4 faces, into a bloom of rectangular suction suitable for the section to be rolled.

Rolling. — Each bloom, previously improved by shearing at the head and foot, provides, after rolling and cutting up by the hot saw, two rails 27 m long with a section of 50 kg/m or a number of shorter rails of a total length corresponding to requirements.

The minimum scrap of 25 % cut off the head of the ingot is in reality 28 to 30 % and the total scrap from head and tail generally amounts to 33 %, say 1/3 of the ingot by weight.

The importance of the waste at the head arises per force from the specification, which does not allow any pipe or harmful segregation.

Rolling should be completed at the lowest possible temperature so as to obtain rails having the best mechanical characteristics.

Superficial longitudinal lines of cracks in the head of the rail and especially in the flange due to blisters elongated by rolling, are considered to be serious defects and are ruled out of supplies. For this reason, the mills have been led to adopt indicating marks showing the run of cracks so that they will be cut out in the first passes of the shaping groove so as to oppose the orientation of the dendrites of the first solidification directed at right angles to the faces of the ingot.

Heat treatment of the extremities. — At the commencement of this article we noted that the ends of all rails of 27 m or longer that are fished, are heat treated, in order to secure additional hardness of the tread, of the surfaces for fishplate joints and of the web at the points where the fishbolts have to be drilled.

This treatment is applied, when the rails leave the rolls, without any previous reheating, by means of compressed air jets. Suitable jigs to fit the rail sections are used for this purpose (1).

This treatment has been generally applied since 1935, has to day proved its utility and the breakages or destruction of the extremities, as well as the cracks in the holes for fish bolts have been almost entirely abolished.

The graph (fig. 1) shown hereafter shows the increases in hardness normally obtained by this process.

The Specification gives particulars of the conditions which have to be satisfied by the ends treated and the characteristics called for are the subject of additional verification, independent of those checks concerning the rails proper.

These checks are made on the test pieces treated at the same time as the ends of the rails supplied.

After the treatment of the extremities, the rails are passed to the bending machine or slid mechanically on the cooling grid at the same time bending

(1) See *Bulletin of the International Railway Congress Association* July, 1936, « Heat-treating the ends of rails », by J. SERVAIS.

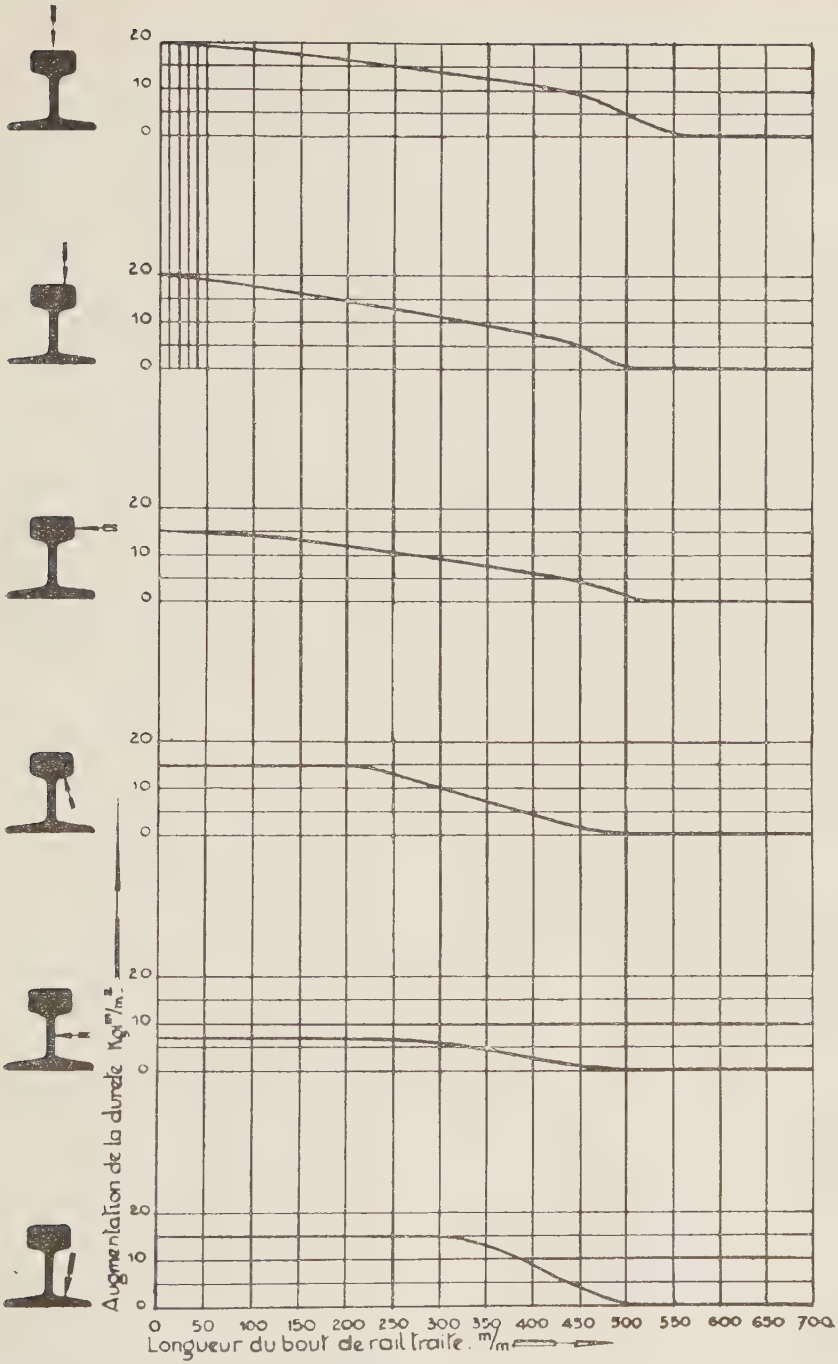

20
10
0
Augmentation de la dureté Kgm/m²
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700
Longueur du bout de rail traité. m/m

Fig. 1. — Increase of hardness obtained by heat treatment of one extremity of a rail of type 50 kg/m and tensile strength of 70 kg/mm² (44.44 t per sq. inch.).

Longueur du bout de rail traité = Length of a piece of rail treated m/m. — Augmentation de la dureté = Increase of hardness kgm/m².

them to a predetermined set, so that after cooling they will approach a rectilinear position.

They are then taken to the finishing machines where they undergo a strictly controlled straightening and thence to the milling machines or saws and drills in order to give them a predetermined length and to drill the holes. In up-to-date machines, sawing to length and drilling is done simultaneously.

Taking into account the fact that the effect of heat treatment of the rail ends diminishes with the distance from those ends, it is important to see that the output of rails at the rolls (before treatment) is arranged for producing minimum overlengths so that cutting the rails to fixed lengths may involve the removal of a minimum of metal at each extremity.

Drilling the holes. — Following on various laboratory tests (extensometer measurements and trials with alternate stresses by means of a pulsator) the French National Railways was able to ascertain that the number of alternations which a rail could withstand, (which test gives us a measure of its life) increases rapidly in the inverse ratio of the diameter of the holes (1).

Basing their action against the fissuration, the S. N. C. F. carried on the struggle against the cracks in the holes bored for the fish bolts, which are at the root of the fractures and failures occurring, by reducing the diameter of the bolt holes from 32 mm, to 25 mm; this in turn, in order to retain the same amount of expansion, led to a reduction of the diameter of the fish bolts and to the raising of their strength in tension.

The results obtained in practice appear to be very satisfactory.

We would point out moreover that as an additional precaution, the S. N. C. F. replaced the ordinary drilling by milling. The operation is effected in two movements by the same tool, that is to say the forward part of the tool acts as an ordinary twist drill, cutting a hole of smaller diameter while the remainder of the tool is formed as a milling cutter which finishes the hole to the final dimension. In this way, the walls of the hole are left smooth without any burr.

For the borings, the S. N. C. B. provides for the holes to be truly cylindrical, with thoroughly smooth walls, without burrs and having the edges slightly chamfered.

This rule added to the advantage obtained by the heat treatment of the ends is considered satisfactory, the more so as the treatment at the extremities increases their resistance to crushing.

Shock. — The test applied by this term is in reality a bending test produced by percussion, since after absorbing the work of 6 000 kgm developed by the dropping of the monkey weighing 1 000 kg from a height of 6 m, the test bars resting on the rail flange supported at a distance of 1 meter apart, show a flexure greater than 50 mm.

This test, applied *to all the drop tests for all the ingots,* forms a fundamental test, at small cost, which adequately guarantees the absence of fragility in the rails and enables the regularity of the

(1) See note by M. PALMÉ, already quoted.

material supplied to be gauged by the flexures produced, while at the same time showing up the longitudinal fissures which may exceptionally appear at the surface of the flange subjected to tension.

It should be noted that the inspector, taking advantage of the licence provided by the Specification, subjects a selected number of test pieces which have already been tested by the falling weight (1). These supplementary shock tests are made in the same way, the test piece (supported by the flange) or with the test piece turned alternately in the other sense (2).

Among the test pieces for the shock-bending test, certain ones are intended to be used for controlling the texture (grain) of the metal. These test pieces are notched and afterwards broken by blows (shocks). The examinations are directed to the section of the metal at the rupture (fracture), this may not show any shrinkage and should present a close and regular grain.

Tensile strength. — These tests are applied to 25 % of the ingots cast and serve to determine the apparent elastic limit, the breaking load R, the % elongation A %, the % contraction (in tension) as also the index of quality R + 2.5 A which may not be less than 106.

The remaining tests :

Resilience test on 20 % of the casts;

Macrographs and Brinell hardness of 12 % of the ingots;

Micrographs and chemical analysis by borings,

are added to the shock tests, as well as grain and tensile tests, together furnish sufficiently complete indications to enable the inspectors to form an opinion on the regularity and the quality of the rails making up the lot submitted for inspection.

The strength may vary between 70 and 80 kg/mm² (44.44 and 50.79 t. per sq. inch), thus allowing a margin in the factory of 10 kg. It should however be noted that the greater number of the test figures lie between the limits of 72-80 kg/mm² (45.71 and 50.79 t. per sq. inch) tensile strength.

Moreover according to the recommendations, the rail makers are obliged to try to keep their product within the upper ranges of the scale of authorised strengths.

The minimum elongations may vary between 14.5 and 10.4 % to meet the quality requirements.

The maximum tensile strength of 80 kg/mm² corresponds to a carbon content of 0.50-0.52 % with a minimum of 1 % of maganese.

With the Thomas (basic) steels, it is not advisable to go beyond these figures for carbon content, on account of the increased fragility due to the increase in perlite of the structure; unless the fatigue

(1) The supplementary shock tests are based on documentary evidence.

(2) We would point out that among the various criteria for quality of rail welds to which the S. N. C. B. periodically refers, (beside micrographic examinations and pulsator alternations) the shock test likewise appears. This latter differs from that prescribed for the manufacture in that they use a monkey of 500 kg falling from a height of 4 m. The test samples of 50 kg rails, electrically welded, and annealed, are normally subjected to 6 blows stressing alternately the head of the rail and the flange, in tension.

of the rail is reduced by using a heavier section, concerning which we shall comment in our conclusions.

In the scale of strengths in tension provided for, the apparent elastic limits usually lie between 39 and 46 kg/mm² (24.76 and 29.21 t. per sq. inch). For the ends that are heat treated, this limit is usually extended to over 50 kg/mm² (31.75 t. per sq. inch).

Resistance to wear. — The idea of this feature is closely related to the tensile strength. This is why there is a tendency to aim at increasing the tensile strength in order to improve the wearing qualities; the danger of the resulting brittleness however opposes this tendency.

This leads us to consider the notion of « *Wear* » which has often been in question, both in regard to rails as well as to tyres.

In this connection, it is not without interest to remember that once they are in service, rails and tyres are subject at the surfaces in contact and as a result of the load stress, to cold-rolling or hammering which progressively increases their initial hardness.

For tyres made of steel of 80 kg/mm², this superficial hardness is of the order of 100 kg after 2 or 3 weeks of running under load, whereas the cold-rolling of the rail heads unavoidably takes place much more slowly and requires many months, even several years according to the density of the traffic, before reaching a superficial hardness of 90 to 100 kg.

Unfortunately, during this period of self-adjustment the rail maintains a surface which is increasingly vulnerable and which makes it susceptible to the irregularities or defects resulting from imperfections in the tyres or from skids and pivoting of the heavy axles.

And yet, comparisons made in service lead to confirmation of the fact that resistance to wear in rails of basic steel is, with the same resistance to traction, better than that of rails produced by the Siemens-Martin or Bessemer processes.

Under the title « The resistance of steel to abrasion », we find in the « *Railway Engineer* » of March 1925, an account of the tests made at that time by an English railway company who carried out tests for wear over long periods with rails placed side by side on a curve of small radius and carrying particularly heavy traffic.

The wear of the different rails took place rapidly enough to prevent the corrosion effect from interfering so that it could be neglected.

Loss in weight is the strictest criterion for realising, calculating and characterising the wear.

Moreover periodic weighing of the rails in the test were undertaken.

The results are tabulated below as also the analyses of the metal of the rails under this test.

In these tests, the rails of Thomas steel showed up better than the others, in spite of a smaller carbon content; but having a higher manganese percentage.

Following on systematic measurements made on main tracks, the S. N. C. B. found the annual vertical wear of the rail tread to be of the order of 0.1 mm for a daily traffic circulation of 10 000

Wear	Quality	Chemical composition		
		Carbon	Manganese	Phosphorus
Thomas	100 (basis)	0.46 %	0.98 %	0.047 %
Martin basic	106-120	0.60 %	0.76 %	0.030 — 0.036 %
Bessemer	186	0.51 %	0.81 %	0.058 %

tons, corresponding to an average passage of 700 axles.

In general, it is realized that if we leave out of account the rails laid in zones that are very highly stressed, such as sections subject to braking or to frequent skidding or even on curves of small radius, *renewal of rails is not the result of wear properly speaking,* but due to local damage or to fractures : fracture or deformation at the extremities, fracture of the solid rail, cracks, depressions, pealings, wear of the fish plate bearings, etc.

Besides this the extent of the need for used rails for equipping and maintenance of secondary lines and accessory short tracks is so high that these requirements can only be met by using rails taken from main lines, before they have reached the limits of wear fixed by the regulations.

For very important main lines the limit of vertical wear allowed on the tread is about 4 mm (5/32″).

Renewal is carried out after the rails have carried the load of 700 × 360 × 40 = 10 080 000 axles approximately.

For main lines with small traffic, the limit for life of rails is estimated at 50 years.

Resilience. — The tests are carried out on 20 % of the casts for each series of supply. They constitute a wide view of the conditions indicating the degree of fragility of the rails.

Each trial includes 3 test pieces of the Mesnager type (with notch 2 mm deep rounded at the bottom) taken from the axis of symmetry of the section : one of these is sunk in the tread below the rolling surface; another halfway up the web and the third close to the surface of the flange where it supports the rail. The position of the notches is given in a plan of the test-pieces attached to the Specification.

The minimum figure of 2 kgm to be reached by one of the 3 test-pieces of a particular rail, is not very severe, but it also aims at the hardest rails of 80 kg/mm² as well as those of 70 kg/mm²

The recorded results show that carefully treated products supply more than 70 % of resiliences equal to or better than 3 kgm; the remainder show a majority of resiliences between 2 and 3 kgm.

Resiliences below 2 kgm are accepted, provided one of the three test specimens

from the same test batch reach the prescribed minimum of 2 kgm.

Macrographs. — This type of examination practised by the S. N. C. B. since 1923, forms a valuable means of controlling the homogeneity of the metal.

No injurious segregation is tolerated in the rails, i.e. no noticeable concentration of sulphur is allowed.

The macrographs are obtained by the Baumann method of taking impressions on slices cut off ingot heads. Certain impressions may be taken similarly from the bottom of the ingot for checking the homogeneity of the metal.

From the result obtained from the slices taken from 12 % of the ingots, depends the use that the inspector may make of his right to cut more slices and to go on with the checks until the moment when his mind is definitely made up on the question of absence of harmful segregation which would otherwise destroy the value of the metal supplied

In order to serve as a guide in assessing macrographic impressions, the S. N. C. B. has attached to the Specification a table showing a certain number of macrographic limits.

Brinell hardness. — The slices cut for the macrographic impressions are likewise used for controlling the Brinell hardness.

These tests (of hardness) bear to a greater degree on other casts than those which served to provide test-pieces for measuring tensile strength; so that actually, the total number of checks on the quality of the metal for rails, is very noticeably increased.

Each Brinell test includes two impressions : one taken on the surface of the tread; the other on the cross section taken at half the height of the rail-head.

The diameters of impressions taken in this way must lie between 3.9 and 4.25 mm, these figures practically correspond to strengths from 70 to 80 kg/mm^2.

Micrographs. — These controls were effected by cutting samples from bore holes in several slices of rails of each batch. The object was to verify that the rails were free from structure due to overheating and for the ends subjected to heat treatment, to verify the improvement in the metallic structure obtained.

Chemical composition. — Before the S. N. C. B. selects the samples intended for verification controls, the manufacturers must supply full analyses of all the casts made for each batch of the manufacture.

The S. N. C. B. controls these analyses by means of boreholes made in their laboratories while obviously conceding certain variations in the contents arising from the fact that the analyses furnished by the producer are those taken at the steel works before the ingots are cast, whereas the analyses for control concern the finished product, which alone interests the user.

The composition of the rails delivered to the S. N. C. B. are usually to be found within the following percentages :

Carbon :	0.44	to	0.52 %
Manganese :	0.85	to	1.15 %
Sulphur :	0.03	to	0.05 %
Phosphorus :	0.04	to	0.075 %
Silicon :	0.12	to	0.20 %

The Specification lays down that the sum of the contents in sulphur and phosphorus may not exceed 0.12 % and this in order to prevent these two harmful elements from having at the same time the maximum content allowed for each of them.

The steel experts can nowadays control the *sulphur* by the action of carbonate of soda on the molten metal where it leaves the cupola or the mixer.

The decomposition of the carbonate of soda used in this way forms a very fluid slag which collects the impurities of the cast metal and in particular a high proposition of sulphur. This favours the elimination of inclusions and of the products of internal reactions and the resultant degasification due to dissociation greatly modifies the structure of the metal.

These effects by the carbonate of soda on the liquid cast are thus not limited to a simple desulfuration and it is necessary to take into account another and much more interesting action than the reduction of the sulphur content, namely the fact that the carbonate of soda purifies the cast by considerably diminishing impurities such as : oxides, silicates and other non-metallic inclusions.

As regards the *phosphorus* and its elimination when the metal is being refined, we have already drawn attention to the remarks by Dr. CANARIS and it is clear from the results obtained in practice that without unduly sacrificing to increasing brittleness, it is possible to allow a phosphorus content up to 0.08 %.

All metallurgists are familiar with the hardening effect of phosphorus and experiments have shown that with a moderate content of that element, i.e. within the limits we have indicated, resistance to wear is increased without injuring the intrinsic quality of the metal.

Moreover, it should be noted that with very low percentages of phosphorus (only to be achieved by a prolonged overblow) corresponding to increasing oxidisation of the metal and to rapid rise in the nitrogen content — an impurity, which thanks to the rise in temperature, is dissolved in the molten iron, finally emphasizes the ageing tendency of the steel.

We would also point out that phosphorus, like sulphur has the undesirable tendency to liquation where the segregation is most marked.

Manganese, added at the end of the process under the form of ferro-manganese, is an element which makes an interesting contribution having a deoxidising effect on the steel bath through the formation of CO and MnO.

It combines readily with sulphur to form MnS, either isolated or coupled with FeS.

Manganese also add to the hardening effect of the carbon and favours the formation of perlite by lowering the point of conversion and in its lamellar form, this perlite improves resistance to wear.

Hence the ultimate action of manganese has a certain hardening effect which allows the carbon content to be limited and thus to avoid brittleness.

Silicon. — The minimum content of 0.12 % of silicon laid down for rails has its origin in the fact that the old type of Bessemer rail in acid steel

showed good resistance to wear which was attributed to the presence of a certain proportion of residual silicon.

This proportion usually varied, in rails, from 0.3 to 0.5 %.

This state of affairs, combined with the well-known deoxidising power of silicon, led to research for the same effects in the basic products (Thomas).

In the case of basic (Thomas) steel, as opposed to what takes place with Bessemer acid steel, the silicon content in the cast metal is eliminated by oxidation and the silicon is at once stabilised by the basic slag.

Hence at the end of the operation, there is no residual silicon and the desired silicon content in the metal can only be secured by additions at the end.

Deoxidation takes place according to the formula :

$$2\ FeO + Si = 2\ Fe + SiO_2$$

The Si fixes the oxygen in the unstable solid compound FeO to form the stable compound SiO_2 and thus prevents formation of gaseous CO by reaction between the metallic oxide and the carbon dissolved in the steel.

On the other hand, the Si can be combined with the iron under the forms : FeSi; Fe_2Si; Fe_3Si; $FeSi_2$; but, at low contents, up to 0.5 % it only occurs in the form of Fe_2Si dissolved in the iron. As such it operates as a slight hardener, increasing the elastic limit and the breaking strength but slightly reducing elongation.

In the basic process, whether as Siemens-Martin or Thomas steel, the addition of silicon to oxidised metal gives rise to the formation of SiO_2 and the metallic Si entering into solution as Fe_2Si is only the remainder of a larger quantity partly oxidised.

The presence of Fe_2Si in the steel is therefore always coupled with the formation of a certain quantity of SiO_2 which is either eliminated or will remain included according to the chemical form in which it appears : i.e. pure SiO_2 or combined with other oxides in the form of silicates, according to the temperature of the steel, the rate of solidification of the ingots, etc.

It is a well-known fact that high contents of Si in steels give rise to numerous longitudinal lines which are seen on the finished products and have nothing to do with the defects of ingots properly speaking. These lines are so many fine cracks which are detrimental to the quality of the products.

The drawback is due to the fact that the SiO_2 appears in the steel bath in the form of thin flakes, which in spite of their low density are not readily decanted and do not rise freely in the slag.

In the steels having a low content of Si, say not more than 0.25 %, this defect is not noticeable but it is necessary to add the Si to a very fluid bath so as to allow the SiO_2 formed to be eliminated before the metal solidifies.

In the course of the years 1922 and 1923, the minimum content in Si specified for the rails by the Belgian Railways was 0.20 %, which forced the manufacturer to allow for up to 0.25 % and more, in order to avoid falling below the specified minimum.

But following numerous rejections due

to the occurrence referred to above, this minimum content was reduced to 0.12 % after 1924.

The S. N. C. B. considers it desirable to maintain this figure.

Finally we can note that silicon does not possess a marked tendency to segregation.

Aluminium comes in as a last resort at the steel works for killing the steel by a moderate addition in the ladle or in the ingot mould.

According to recent research, the killing of the aluminium, apart from its effect in refining the grain of the metal, would be effective in countering the ageing tendency of the steel, by the formation of aluminium nitride which neutralizes the harmful action of the nitrogen. This nitride of aluminium would then be regarded as an inclusion in the steel without it having any other injurious effect.

Tolerances on dimensions. — The tolerances on dimensions are clearly set out in the Specification and are particularly strict for the dimensions of chairs for the fishplates, where the opening for the plates may not differ from the theoretical cross-section by more than 0.5 mm at the outside.

Guarantee. — Since 1948, rails are subject to a guarantee of good condition in service for a period of 10 years. This guarantee refers to any defect which can be put down to faulty manufacture and the manufacturer is bound to replace free of charge the rails recognized as defective or to pay amounts representing the value of the rails at the time of their removal.

Results, conclusions and prospects for the future.

Without detracting in any way from the value of the Martin process, to which we may have to return when the case arises of executing certain special grades of very hard steel (for instance, rails for curves, points and crossings, etc.) starting from materials of the highest class, we may conclude from what we said above that the care with which the manufacture of Thomas (basic) steel is carried out and the various controls to which they are subjected enable us to obtain within the range of normal resistances, results that are comparable, if not superior to those provided by the Martin or Bessemer processes.

This statement is supported by the annual statistics of breakages.

In the results obtained, it is not possible to establish the portion which should be attributed to the quality of the rails and that which is due to the methods of track maintenance and to reinforcement of the superstructure.

We will simply confirm, as is only fair, that the combined efforts of the services of the S. N. C. B. have resulted in a very substantial reduction of the number of breakages and that is what is important to record in evidence.

Although they include rails of old pattern and of different sections still in use (about 25 % of the total kilometrage of the main lines), certain of which date from 1898, these statistics, illustrated in the diagram (fig. 2), testify to the degree of safety achieved.

This diagram only shows the situation

for the years 1926 to 1939; the period 1940 to 1945 corresponding to the German occupation and that of 1946 to 1949 to the reequipment and to the reconditioning of the network.

As an additional argument, we would add that in the 25 years which we have considered, the S. N. C. B. has not had occasion to record any catastrophe nor any serious accident of any gravity that could be imputed to breakages or destruction of rails.

And this is why, taking into account the density of traffic and the undoubtedly difficult running conditions, we are not afraid to maintain that the criticisms periodically directed against rails made of basic (Thomas) steel are above all published for commercial reasons without any reference to the technical reality.

The principal rules which we have reviewed, coupled with the skill and long experience of our steel experts, are qualified to guarantee to the very greatest degree the uniformity in quality of the rails rolled in basic (Thomas) steel.

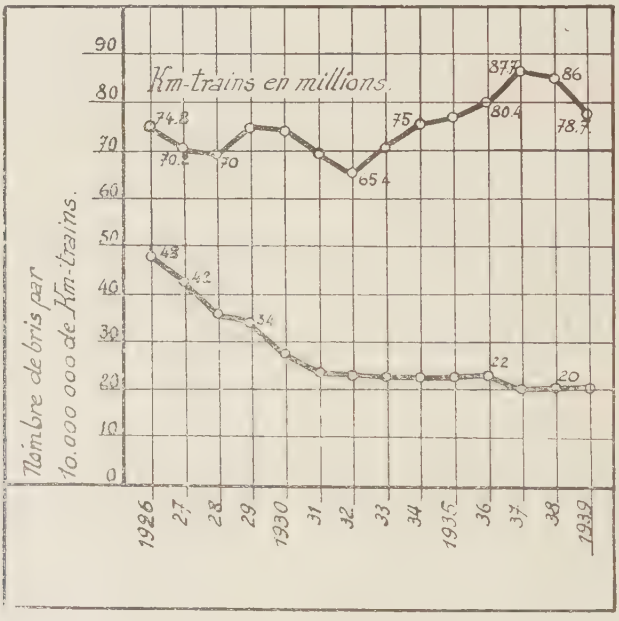


Fig. 2.

Legends : Km-trains en millions = Km-trains in millions. — Nombre de bris par 10 000 000 de Km-trains = No. of breakages per 10 million Km-trains.

It is in the needs arising from an intensive exploitation that the requirements defined in the specifications of the S. N. C. B. find their justification. It goes without saying that there is no call to apply the rules slavishly to all supplies of rails without distinction since such requirements are costly and their indis-

criminate application would not be justified for material intended for secondary networks.

As regards the future, the opinions which are held to-day in favour of increasing the weight of the rails are increasingly supported on account of the heavy charges for manual labour resulting from the maintenance work on the tracks and this, in spite of all the efforts to improve matters by organisation.

It is certain that with a heavier section, we should profit by the advantage of a higher moment of inertia, which would reduce fatigue of the rail, i.e., the pressure of the rail on the sleepers and the pressure of the latter on the ballast, without having to modify the weight of the other elements : attachments, ballast and spacing of sleepers.

There we have moreover the conclusions arrived at by all the engineers who have systematically studied the superstructure of the track.

The greater rigidity of the rail will allow one to emphasize without danger and to a certain extent the hardness of the metal.

A slight increase in the carbon content would favour the polyhedric structural arrangement of the steel by diminishing the amount of eutectoidal ferrite, to the benefit of the perlite, which in other words would mean an improvement in the resistance to wear.

Finally, the increased cost due to the increased weight per metre of the rails would be compensated for by economy in maintenance provided this increase in weight is proportional to the benefits to be gained therefrom.

It is well at this point to remember that the S. N. C. B. had already utilized heavy rails of 52 and 57 kg per metre, which at the period of their adoption (1886 and 1907) contrasted with the lighter sections used in Europe. And it is right to add that if these sections were abandoned in the end, it was in no sense the principle of the heavy rail that was the reason for this action.

The principal causes for this change of policy were :

For the 52 kg rail, the angle of the supports for the fished joints was too small at 1/5 allowing the fishplates to make rapid contact with the web of the rail, thus ruining the jointing.

For the 57 kg, the lack of adaptability of the tools at the works led to retaining the same weight and the same section of ingot whence reduction of the degree of welding and improper diminution of the fall at the head to the detriment of quality. In addition the system of attaching the rail was entirely defective.

If we come to a heavier section, it will be important to look out for the temperature gradients when cooling off takes place, that is to say the need to judiciously distribute the mass of the rail head, the centre-rib and of the flange, as is done in the U. S. A., so that after rolling and cooling off, the rails should be as straight as possible and should only require a very little straightening.

The difficulties of straightening cold are moreover increased with the rigidity of the section and the brutal deformations that result, may open up internal cracks which with the tensions due to contraction are the cause of transverse

cracks so frequently met with in the U. S. A.

As regards the shape of the rail head, it must be governed by the relative positions taken up by rails and tyres according to the sections which they acquire by wear, so as to assure them at any moment of having sufficient contact surfaces for keeping down the unit pressure.

In short, if the efficacity of controlled cooling in the special furnaces was demonstrated for hard steel rails of heavy section, the Belgian and Luxemburger steel works managers would not hesitate to carry out the necessary modifications to their plant in order to benefit by the inherent advantages of isothermal cooling.

[621 .132 .8]

Principles of a projected fireless locomotive,

by Riccardo BIANCHEDI,

Engineer of the Genoa Polytechnical School.

SUMMARY.

Fireless locomotives can be used extensively in shunting and marshalling yards either because of their economy in use or of their reliability in working, which make them particularly suitable for use most advisable in industrial establishments in which there is constant danger.

The following article after making a comparison from the financial point of view of standard steam shunting locomotives and of other forms of storage of energy locomotives, traces the principles of a project which has as principal objective a maximum saving in the cost of installation and utilisation for a given application.

This note ends with a numerical example showing the application of the principles developed.

1. INTRODUCTION.

A fireless or steam accumulator locomotive consists of a locomotive in which the boiler is replaced by a reservoir of hot water under pressure from which can be taken under gradually decreasing pressure and temperature, a quantity of steam produced by the heat of the water under pressure.

From the constructional aspect, a fireless locomotive has a cylindrical or saddle shaped boiler, rivetted, welded or forged in one piece.

In the case of pressures in the boiler of 16 to 18 kg/cm^2 (227 to 259 lbs. per sq. inch) the steam released by the water passes through a pressure reduction valve which reduces the pressure to 12 or 14 kg/cm^2 (170 to 199 lbs. per sq. inch). The steam then passes to cylinders exactly like those of an ordinary steam locomotive.

If fitted with a superheater the steam after leaving the reducing valve passes through a coil in the water of the boiler on its way to the cylinders.

Seeing the source of power is due to an accumulator the fireless locomotive can be compared with the compressed air locomotive and the electric battery locomotive as regards storage of energy capacity.

In the field of traction by accumulators, the essential problem is that of the weight of and the space needed by the accumulator. Consequently, we are at once led to compare these three different methods of traction by these two factors whilst varying the fundamental parameter which, for compressed air and steam storage locomotives, will be represented by the initial pressure of storage.

We get the results shown in Fig. 1 deduced from existing installations and corresponding to the following characteristics :

1) Reservoirs of the fireless and compressed air locomotives are welded and annealed;

(2 Average specific consumption of steam and compressed air 25 kg/ch/h (*) and 22.5 kg/ch/h respectively.

3) Final pressure in the reservoirs : 2 kg/cm² (28 lbs. per sq. inch).

occupies a position between the battery electric locomotive and the compressed air machine.

If the choice of the method of traction by accumulator of energy were made on

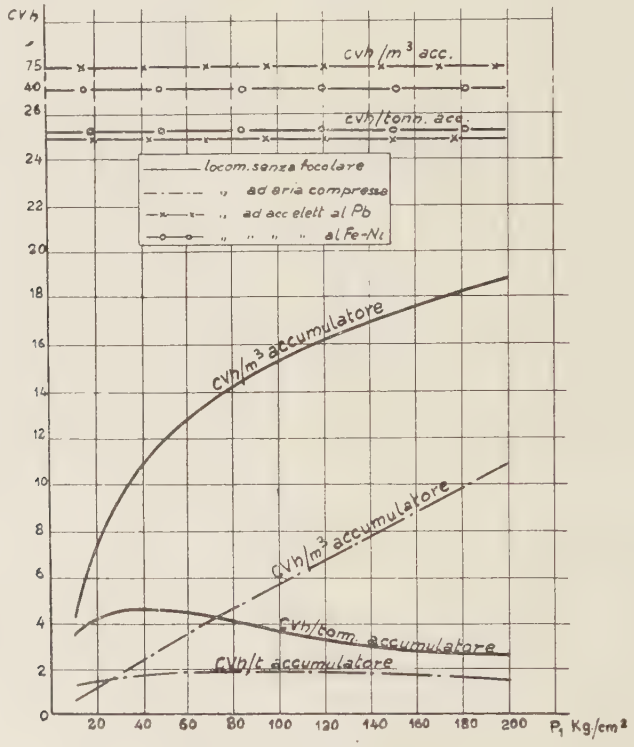


Fig. 1.

Explanation of the Italian terms :

Locom. senza focolare = Fireless locomotive. — Loc. ad aria compressa = Compressed air locomotive. — Loc. ad acc. elett. al P*b* (al Fe— Ni) = Lead (or Nickel-Iron) accumulator electric locomotive.

The diagram shows that from the point of view of weight and bulk per unit of energy at wheel tread, the fireless locomotive weight and bulk only, the choice would go solely to the battery electric locomotive using either lead (P*b*) or nickel iron (Fe - Ni) cells.

(*) kg/ch/h : kg/HP-h.

This choice in actual practice will be affected by the particular needs of each application.

In any event. it is quite certain that compared with electric accumulator locomotives, the fireless locomotive has the advantage of reducing the costs of maintenance of the batteries, the traction equipment and the control gear.

It should be remembered too, that when fireless locomotives replace steam locomotives, the staff can be used straight away whereas with accumulator electric locomotives, it has to undergo a period of training.

Compared with compressed air locomotives, the fireless locomotive is always lighter and takes less space.

The drawback of the three types is generally the great weight of the accumulator : consequently the field of application of traction by stored energy limits itself to working short lines without gradients at low speeds. This is in order to get a good enough transport efficiency within the usual size of locomotives.

This explains why in practice the field for stored energy traction is limited to shunting services alone whether in industrial works or in shunting yards.

The working of such services is based on purely economic considerations. In fact, it is only in rare cases that the operating cost per virtual ton km (TKVR) is outweighed by other factors, except in the case of powder works, arsenals, or tunnels under construction where hygiene and safety impose appropriate solutions.

As such considerations do not lend themselves to a general discussion, we will deal solely with the unit cost of operation mentioned above.

In the four examples to be considered, usual steam locomotive, fireless locomotive, compressed air locomotive and accumulator electric locomotive, the respective expression of the unit operating $C_1 \ldots . C_4$ in lire per TKVR can be determined without difficulty.

These are :

1) Normal steam locomotive :

$$C_1 = \left[0.0185 \cdot q_v \cdot (i_v - i_a) \frac{1}{P_{ci} \cdot \eta_c} \cdot \frac{C}{1\,000} + \frac{2}{3} \frac{30\ G \dfrac{C}{1\,000} H}{T_{vr}} \right] \frac{1}{\eta_{it}} + (P_f + P_m) \frac{H}{T_{vr}} + \frac{S_c}{T_{vr} \cdot 365} \quad \text{lire/TKVR}$$

2) Fireless locomotive

$$C_2 = \left[0.0185 \cdot q'_v \cdot (i'_v - i'_a) \frac{1}{P'_{ci} \cdot \eta'_c} \cdot \frac{C'}{1\,000} \right] \frac{1}{\eta'_t} + \frac{S'_c}{T_{vr} \cdot 365} + \frac{P_m \cdot H}{T_{vr}} \quad \text{lire/TKVR}$$

3) Compressed air locomotive :

$$C_3 = \left(0.0185 \cdot q_a \cdot \frac{0.0223}{\eta_i} l_n p_a \cdot C'' \right) \frac{1}{\eta''_t} + \frac{S''_c}{T_{vr} \cdot 365} + \frac{P_m \cdot H}{T_{vr}} \quad \text{lire/TKVR}$$

4) Accumulator electric locomotive :

$$C_4 = \left(0.0185 \cdot 0.736 \cdot \frac{1}{\eta_m} \cdot \frac{1}{\eta_e} \cdot C''\right)\frac{1}{\eta'''_t} + \frac{S'''_c}{T_{vr} \cdot 365} + \frac{P_m \cdot H}{T_{vr}} \quad \text{lire/TKVR}$$

The symbols have the following values and meanings :

0.0185 energy at the wheel tread in ch/h for one TKVR under the hypothesis that unitary resistance = 5 kg/t;

q_v, q'_v, consumption of steam per ch/h at the wheel tread for a normal steam locomotive ($q_v \simeq 16$ kg/ch/h) and for a fireless locomotive ($q'_v \simeq 25$) of usual type without superheat;

i_v, i'_v thermic capacity of the steam from the feed water in cal/kg;

i_a, i'_a thermic capacity of the feed water in cal/kg;

P_{ci}, P'_{ci}, lower calorific value in cal/kg of the fuel used respectively in the firebox of the normal locomotive and in the stationary boiler for producing the steam needed for the fireless locomotive.

η_c, η'_c respective efficiencies of the boiler of the normal locomotive and of the stationary boiler ($\eta_c \simeq 0.7$; $\eta'_c \simeq 0.8 \div 0.85$);

C, C′ costs in lire/tonne of the fuel used respectively in the normal locomotive and in the stationary boiler. As a general rule for the same calorific value : C is greater than C′.

The second form of the expression between brackets of C, it should be noted, is due to the fact that the standard steam locomotive in shunting or marshalling service runs with its regulator closed about half the booked time. From many tests the time in shunting is about 2/3rds. of the booked time; the locomotive boiler supplies steam to the cylinders during only 1/3rd of this period. During the other 2/3rds it burns coal uselessly. This consumption is evaluated at about 30 kg (66 lbs.) of coal per sq. metre of grate per hour (1).

The other symbols have the following meanings :

G = grate area in sq. m of a normal steam locomotive (1.5 to 2 m² [16 to 21.5 sq. ft.] for ordinary shunting locomotives; 3 m² [32 sq. ft.] for the large marshalling yard locomotives);

H = number of hours of working per day;

T_{vr} = number of TKVR;

η_t = average efficiency of the movement, or ratio between the average weight of the rake hauled and the total weight of the train of average make up for each of the four conditions considered;

P_f, P_m = hourly rate of pay of the fireman and driver respectively.

It is to be noted that unlike the other methods the normal steam locomotive requires the services of two men on the footplate.

$S_c \ldots S'''_c$ = annual capital cost of the locomotive in lire-year.

It is necessary to remember that the capital involved relates not only to the

(1) See : « Progresso dell' Ingegneria Germanica », Nov. 1939.

locomotive but also to the accessory installations, the sheds, water treatment plant, ash pits, hydraulic cranes, coaling plant for normal locomotives, fixed installations and apparatus for steam storage for fireless locomotives, compressors and compressed air mains for the compressed air locomotives, charging plant for the battery electric locomotives.

Q_a specific consumption of compressed air : 22.5 kg/ch/h approximately;

η efficiency of the compressor : 0.6 to 0.7.

p_a absolute pressure in kg/cm² of the compressed air.

C'' price per kWh of electric energy for industrial use.

η_m overall efficiency of the engine and transmission of the accumulator electric locomotive : 0.7 to 0.75;

η_e, efficiency in energy of the accumulators : for lead (P*b*) batteries : 0.75 to 0.8; for Nickel-Iron (Ni - Fe) 0.5.

The expressions for C, ascertained from from very complicated considerations and taking into account several factors which cannot be well defined in a general development, show that a comparison between the costs per unit of transport of the four methods of traction cannot only be done by relating them to particular applications.

2. DETERMINATION OF THE FUNDAMENTAL CHARACTERISTICS.

The data for determining the main characteristics of a fireless locomotive are, apart from the usual ones common to any scheme for a vehicle running on rails, as follows :

1. the total work to be done in TKVR;

2. the maximum drawbar pull;

3. the characteristics of the steam supplied by the stationary plant.

With these figures the next points to be decided are :

1. the most adequate pressure when charged;

2. the capacity of the reservoir.

The determination of these characteristics is subordinated to a study of two fundamental questions; the vaporisation capacity of the mass of water and the specific consumption of steam.

2a. Vaporisation capacity of the mass of water.

Let :

P_1, P_2, kg, be the quantity of water in the container at the beginning and at the end of the period of working;

t_1, t_2, °C, the respective temperatures of P_1, P_2, corresponding to the initial and final absolute pressure p_1 and p_2 atm.

r_m cal/kg, mean calories of vaporisation :

$$r_m = \frac{r_1 + r_2}{2}$$

The quantity of steam released will be : $P_1 - P_2$ kg and can be expressed by the formula (2) :

$$V = P_1 - P_2 = P_1 \left(1 - \frac{t_1 - r_m}{t_2 - r_m}\right) \quad (2)$$

It will be noted that the formula is an approximation, as it covers the total

(2) « Borsig ».

heat of the liquids I_1, and I_{l2} at the respective temperature t_1 and t_2.

This hypothesis is only acceptable when the pressure in the reservoir is of the order of 20 — 25 kg/cm² (284 — 355 lbs. per sq. inch) (see Fig. 2).

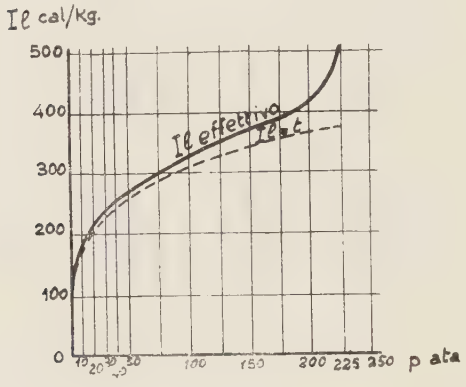


Fig. 2

For higher pressures the difference between the approximate and the real values becomes more and more appreciable and is very marked for the very high pressures (150 atm. and above).

The formula becomes more accurate if I_{l1} and I_{l2} be used in place of t_1 and t_2. We then get WICHTENDAHL (3) ratio :

$$V \cdot P_1 - P_2 \quad P_1 \left(1 - \frac{I_{l1} - r_m}{I_{l2} - r_m}\right) \qquad (3)$$

Formula 3 like formula 2 has the defect, as regards accuracy, of using a value of r_m interpolated linearly between r_1 and r_2. If this can be accepted for slight differences between r_1 and r_2, it cannot when this difference becomes appreciable or when high pressures (above 25 atm.) (see Fig. 2) are used.

In the case of $p_1 = 25$ atm., formula 2 may be made very accurate by using for r REGNAULT's (4). expression :

$$r = 606.5 - 0.695 \cdot t. \quad . \quad . \quad . \quad (4)$$

The limit fixed for r_1 is justified by the fact that it is only for pressures $\leq$ 25 kg/cm² that there is agreement between the values of r given by the formula (4) and the real values (see Fig. 3).

If x be the residual weight of water at t °C and giving the other symbols the known meanings we get :

$$x \cdot dt = (606.5 - 0.695 \cdot t) \cdot dx$$

or :

$$\frac{dx}{x} = \frac{dt}{606.5 - 0.695 \cdot t}$$

whence :

$$\int_{P_1}^{P_2} \frac{dx}{x} = \int_{t_1}^{t_2} \frac{dt}{606.5 - 0.695 \cdot t}$$

In resolving the integral the wanted relation between P_1 and P_2 is :

$$lg \frac{P_2}{P_1} = -\frac{1}{0.695} lg \frac{606.5 - 0.695 \cdot t_2}{606.5 - 0.695 \cdot t_1} \qquad (5)$$

The differences between the values of $(P_1 - P_2)$ given by the formula (2) and formula (5) are appreciable. For example when :

(3) See « Hanomag Nachrichten », 1925 XII: 1927, No. 166.

(4) See « Technique moderne » Vol. XIII, No. 6.

p_1 = 10 kgr./cm²; P_1 = 3 350 kgr.;
p_2 = 2 kgr./cm²,

we get by formula No. (2) : $P_1 - P_2$ = 472 kg;

and by formula No. (5) : $P_1 - P_2$ = 325 kg.

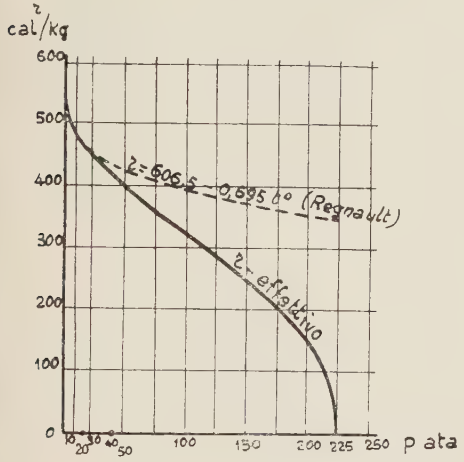


Fig. 3.

The difference exceeds 30 % and a reservoir calculated on formula (2) would give unreliable results.

All we have noted so far shows that the formula (2), (3) and (5) cannot be applied in practice when the charging pressure exceeds 25 atm. For this pressure and more precisely between 0 and 25 atm. Messrs Henschel have carried out tests recorded diagrammatically which give as a function of the initial and final pressures directly the quantity of steam released from each ton of water put in (5). These results agree with those calculated analytically.

(5) See « Henschels- Manual for the Locomotive Builder », 1935 edition.

Once this question is settled we have still to ascertain the quantity of steam $P_1 - P_2$ for a drop of pressure of p_1 to p_2 when $p_1 > 25$ atm. The difficulty resulting from the impossibility of expressing analytically these various factors in terms of P over the whole range of

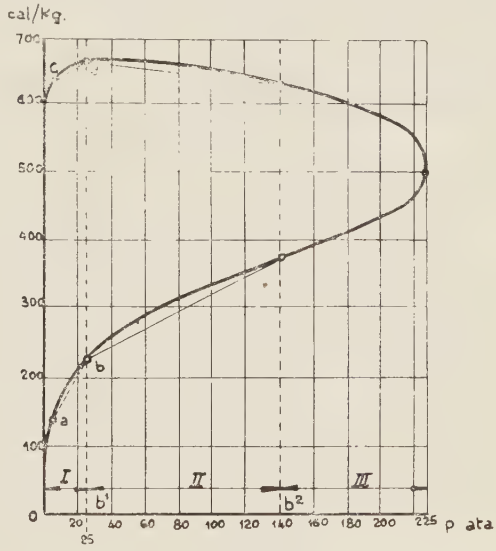


Fig. 4.

variation of the latter is obviated by dividing into three zones the range of the pressures from 0 to the critical pressure of 225 kg/cm² (see Fig. 4); in the two first, p = 5/25 atm. and p = 25/140 atm., we resort to a linear interpolation for r and I_1, in the third P = 140/226 atm, to a parabolic interpolation (6).

If α_v kg/kg be the coefficient of vaporisation which represents the quantity of steam which can be released from 1 kg

(6) See Farmakowsky « Das Verdampfungsvermögen der Hochruck-Wärmespeicher feuerloser Locomotiven », *Die Lokomotive*, Jan. 1944.

of water in the container, the pressure varying between p_1 and p_2 we get :

$$\alpha_v = \frac{Il_{p1} - Il_{p2}}{r_m p_1/p_2} \quad \ldots\ldots \quad (6)$$

in which $r_m p_1/p_2$ represents the mean heat of vaporisation between p_1 and p_2 and we find that in zone III the interpolation gives :

$$\alpha_v = \tfrac{1}{4} [ln\,(p_c - 140) - ln\,(p_c - p_1)] \quad (7)$$

ant factors which affect considerably the actual quantity of steam released, to wit :

1. the variation of the weight of water in question between P_1 and P_2;

2. the loss of heat through the casing;

3. the heat given back to the water by the casing of the boiler.

We have shown (7) that the heat lost through the casing is balanced by that given back by the casing to the water

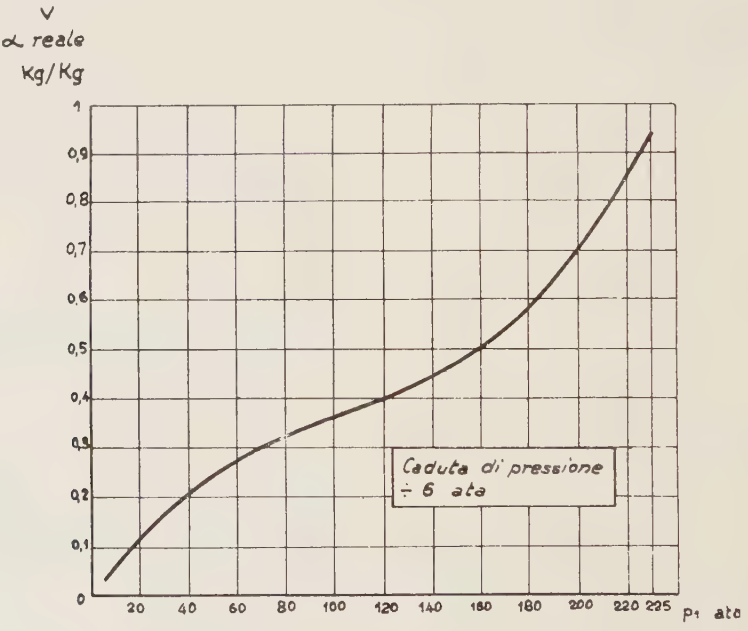


Fig. 5.

N. B. — Caduta di pressione ÷ 6 ata = drop of pressure ÷ 6 atm.

It becomes possible to obtain a very close approximation of the quantity of steam produced $P_1 - P_2 = \alpha_v . P_1$ when the tangents drawn for the interpolation coincide closely with the curve of the actual diagram (see Fig. 4).

This does take into account three important factors which affect considerably the actual quantity of steam released, to wit :

1. the variation of the weight of water in question between P_1 and P_2;

2. the loss of heat through the casing;

3. the heat given back to the water by the casing of the boiler.

We have shown (7) that the heat lost through the casing is balanced by that given back by the casing to the water provided that the latter is well insulated. On the other hand, point 1 ought to be taken into account. The average quantity of water contained in the reservoir during working we have found will be :

(7) See « Die Lokomotive », *ibidem.*

$$\frac{P_1 + P_2}{2} = \frac{P_1 + P_1 - \alpha_v P_1}{2} = P_1\left(1 - \frac{\alpha_v}{2}\right)$$

Consequently, the real quantity of steam will be :

$$\alpha_v \cdot P_1 \left(1 - \frac{\alpha_v}{2} \right) = \left(\alpha_v - \frac{\alpha_v^2}{2} \right) \cdot P_1$$

and not :

$$\alpha_v \cdot P_1$$

From the above, the true coefficient of vaporisation which should be multiplied by the initial weight of water, will become :

$$\alpha_{vr} = \left(\alpha_v - \frac{\alpha^2_v}{2}\right) \ldots\ldots \quad (8)$$

Fig. 5 shows the values of α_{vr} as a function of the initial pressure p_1 calculated by formulae (6), (7) and (8).

This diagram is intended to help the builder.

2b. Specific steam consumption.

As is known the specific steam consumption of a superheated steam locomotive can be expressed sufficiently accurately by the following formula based on many tests [8] :

$$\sigma i = \frac{3\,060\,000 - 3\,300 \cdot n}{T^2} + 8\left(\varepsilon - \frac{210 - 1.14 \cdot n}{T}\right)^2 \ldots\ldots \quad (9)$$

in which :

σi = steam consumption in kg/i. h. p.

η = number of revolutions per minute of the driving wheels.

T = absolute temperature in °C of the steam on admission to the cylinders.

ε = cut off.

The specific consumption for a given effort at the driving wheel tread will be

$$\sigma_e = \sigma_i / \alpha$$

in which $\alpha = 0.7$ approx. is the mechanical efficiency of the locomotive.

Of the three factors which according to formula (9) affect σ in the application considered, T is the most important. Actually in shunting it varies very little when at work and reaches 30 to 35 revs. per minute as the usual wheel diameter is about 1 m and the speed during shunting averages about 6 km/h (3.7 m. p. h.). Furthermore the influence of a variation of ε in the range of values normally used for admission is not appreciable (see Fig. 6).

On the other hand the influence of T is appreciable as is shown by the same figure. The influence of the use of a superheater in a fireless locomotive is shown by Fig. 7. In order to use standard motion parts all fireless locomotives whether mean or high pressure are fitted with an automatic or hand operated device which reduces the pressure to 10 to 12 kg/cm². The flow of the steam through this device is given by an isoentalpic which, provided the initial pressure does not exceed 35 atm., shows the steam at 12 atm. will be superheated. Above 35 atm. at the end of expansion the steam is saturated and very wet with a relatively low temperature (see Fig. 7). In modern medium and high pressure fireless locomotives

(8) See LANGROD : « The specific steam consumption of superheated locomotives », *Bulletin of the Congress*. April, 1938.

the steam is superheated at the end of expansion by passing it through a coil immersed in the water carried (« Gilli » cycle) (9).

In this way the steam is superheated appreciably. We can see this in Fig. 7 without superheating, calculated by means of the diagram in figure 6, and the percentage saving obtained with superheating.

If the saving can be taken as negligible for pressures up to 26 atm. it is very marked above this and most substantial for high

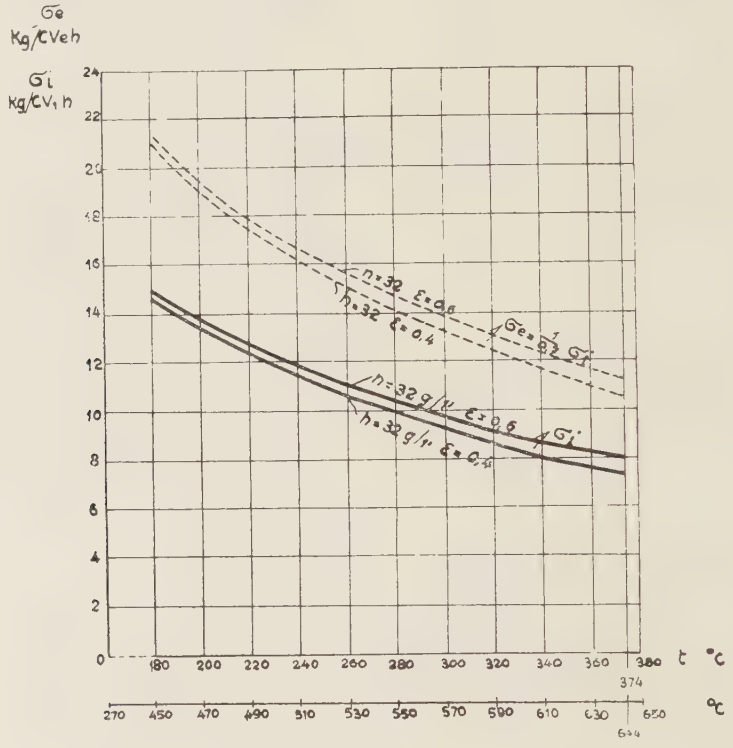


Fig. 6.

which as a function of the absolute pressure, p_1 in the reservoir gives the absolute temperature T of the steam after expansion at consistant thermal capacity p_1 ./. 13 atm.

The same diagram also gives the curves of the specific consumptions with and pressures of and above 80 kg/cm² (1 137 lbs. per sq. inch).

2c. Choice of charging pressure.

Having ascertained the service needs and having established the characteristics of the locomotive to meet them, the selection of the pressure should be based mainly on the following principles :

(9) See « Krupp Mitteilungen » May, 1941.

1. Keep the total weight of the reservoir and the water therein contained as low as possible.

2. In accordance with the preceding condition, use the lowest possible pressure so that the auxiliary equipment may be the simplest and cheapest.

For a given amount of work A in TKV, the work to be done at the wheel tread to be accumulated is 0.0185 × A ch.-h. and the quantity of steam needed therefore is :

$$\Sigma = A \cdot 0.0185 \cdot \sigma_e^m$$

in which σ_e^m is the average value of σ_e

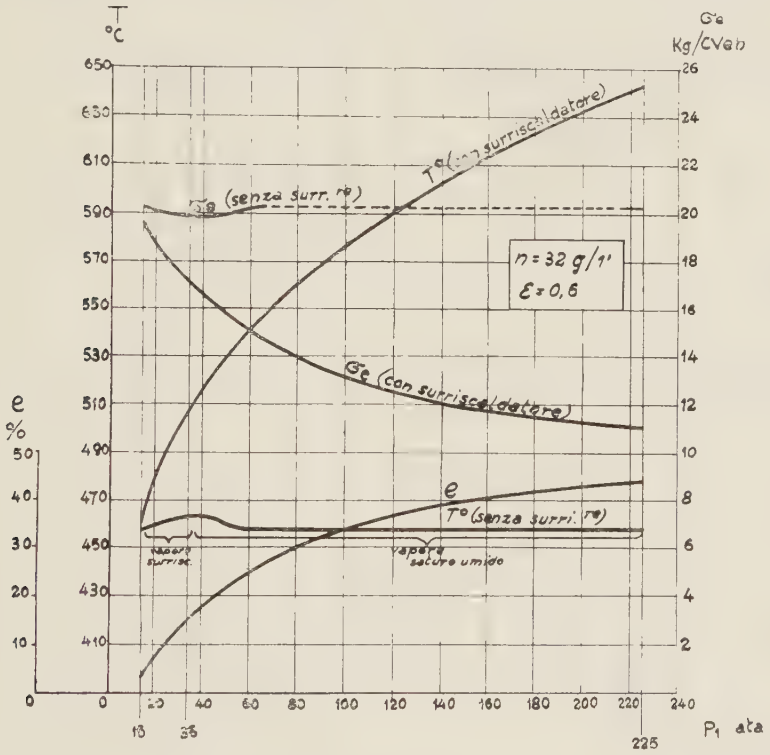


Fig. 7.

Explanation of the Italian terms :

Con (senza) surriscaldatore = With (without) superheater. · Vapore surrisc. = Superheated steam. — Vapore saturo umido = Saturated wet steam.

With this object in view, we must seek to define the total weight $Pt = P_1 + P_s$ kg as a function of the charging pressure p in which P_1 is the initial weight of water stored and P_s the weight of the reservoir casing.

between the initial charging pressure p_1 atm. and the final $p_2 = 6$ atm. obtained by means of Fig. 7.

It is necessary to point out while in the case of medium or low pressure fireless locomotives the reduced pressure of 12

kg/cm² (170 lbs. per sq. inch.) at the cylinders is normal, it is well to make the cylinder dimensions oversize so that the locomotive can develop the maximum tractive effort required even with a pressure of 6 kg/cm². When the reservoir pressure is 12 kg/cm² or less, the reducing valve automatically becomes a by-pass and the steam flows directly from the reservoir to the cylinders.

For the reasons given in 2 *a*) the quantity of water P_1 will be given by :

$$P_1 = \frac{\Sigma}{\alpha_v - \frac{\alpha_v^2}{2}} = A \frac{0.0185 \cdot \sigma_e^m}{\alpha_v - \frac{\alpha_v^2}{2}} \text{ kgr.} \quad (10)$$

in which α_v is the mean coefficient of vaporisation obtained from formulae (6) and (7).

As the initial volume taken up by the water should be about 5/6 of the volume V_s m³ of the reservoir (9) called v_{ai} m³/kg the specific volume of the water at the relative temperature and at pressure p_1 will be :

$$V_s = 6/5 \cdot P_1 \cdot v_{ai} \text{ m}^3 \ldots \quad (11)$$

Once the length L_s in m is fixed the interior diameter D_s of the reservoir is given by :

$$D_s = 2\sqrt{\frac{V_s}{L_s \cdot \pi}} \text{ m.} \ldots \quad (12)$$

The wall thickness S is given by the formula (10) :

$$S = \frac{p_1 \cdot 1\,000 \cdot D_s \cdot x_1 \cdot x_2}{200 \cdot R \cdot z} \text{ mm} \ldots \quad (13)$$

in which :

x_1, the elastic limit coefficient depends upon the temperature of the fluid (See Table I);

TABLE I.

t °C	200	220	240	260	300	340	374
x_1	2.1	2.2	2.3	2.4	2.6	2.8	2.85

x_2, factor of safety : 1.7 for forged drums; = 2.10 for welded drums.

R, breaking strength of the material used for the casing kg/mm².

z, factor of efficiency of the plate joints (see Table II).

TABLE II.

Type of joint :	z =
Forged drum	1
Arc welded drum, not annealed. .	0.7
Arc welded and furnace annealed .	0.8

The expressions (10) to (13) enable us to calculate the total weight P_t. We could express P_t by a general formula containing all the factors involved. The great complexity of such a formula and the difficulty of expressing it closely in terms of p_1 owing to the many factors in it makes it of little practical value.

We will therefore make a concrete application. Let :

A = 4 000 TKV.

L_s = 6 000 mm.

(10) See SPREGA « La sicurezza nei calcoli di stabilità » (Il *Calore* III, IV, 1937).

The calculation of P_t for various values of p_1 defines the diagram of figure 8. This calculation is reproduced integrally in Table III.

This table shows the weights : P_1 the initial weight of water; P_s of the one-piece forged container and P'_s of the electrically welded and annealed drum, and also $P_1 + P_s$ and $P_1 + P'_s$ of the charged reservoir in the two examples taken.

An examination of Fig. 8 leads to certain valuable conclusions : first of all the volume of the reservoir increases directly and continuously as the charging pressure. From the point of view of the capacity of the locomotive, it is desirable therefore to use much higher charging pressures.

This is not so as regards the weight of the charged reservoir. Actually whether

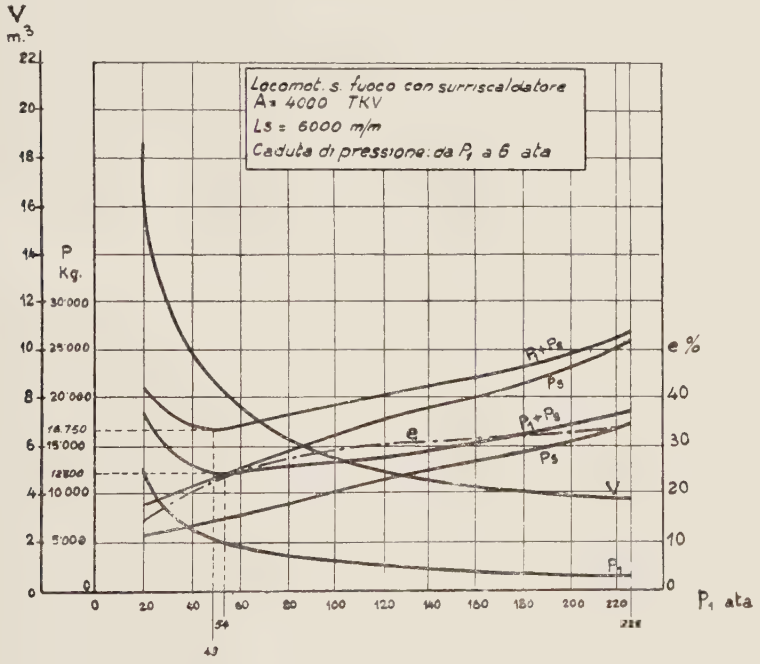


Fig. 8.

Explanation of the Italian terms :

Locomot. s. fuoco con surriscaldatore = Fireless locomotive with superheater. — Caduta di pressione : da p_1 a 6 ata = Drop of pressure from p_1 to 6 atm.

The table also shows the saving of weight in % obtained by using a forged reservoir in place of the welded design, and also the space occupied in V_s, m^3 by the reservoir.

of welded or forged construction this weight is a minimum for a certain pressure p_1. In the case dealt with in Fig. 8, this optimum pressure is 49 atm. for the welded and 54 atm. for the forged reservoir.

Fireless locomotive with superheater — A = 4 0

p_1 atm.	$\alpha\ vr$ (fig. 5)	$\sigma\ e^m$ kg/ch. h. eff. (fig. 7)	$P_1 = \frac{A \cdot 0.0185 \cdot \sigma e^m}{\alpha\ vr}$ kg	t °C	v_{ai} m³/kg × 10⁻³	$V_s = 6/5\, P_1\, v_{ai}$ m³	$D_s = 2\sqrt{\frac{V_s}{L_s \cdot \pi}}$ m.
20	0.11	19	12 760	211	1.210	18.5	1.99
40	0.2	18	6 440	250	1.26	9.75	1.44
60	0.27	17	4 640	274	1.30	7.25	1.24
80	0.32	16.5	3 820	294	1.42	6.50	1.175
100	0.36	15	3 100	309	1.47	5.5	1.08
120	0.40	14.8	2 730	323	1.54	5.05	1.05
140	0.44	14.2	2 380	335	1.6	4.56	0.99
160	0.50	14	2 060	346	1.7	4.24	0.95
180	0.525	13.5	1 900	355	1.80	4.10	0.936
200	0.69	13	1 390	364	1.95	3.26	0.833
225	0.93	12.8	1 020	374	3.10	3.8	0.9

0 mm drop of pressure from p_1 to 6 atm. — R = 42 kg/mm².

ervoir	z per reservoir		s mm. per reservoir		Weight of the reservoir kg		Total weight kg		$e\,\% = \frac{P's - Ps}{P_1 + P's} \cdot 100$
welded	forged	welded	forged	welded	Ps forged	$P's$ welded	$P_1 + Ps$	$P_1 + P's$	
			17	26	5 820	8 900	18 850	21 660	14.2
			28	44	6 620	10 200	13 060	16 640	21.5
			38	59	7 700	11 700	12 380	16 340	24.5
			49	76	9 300	14 200	13 120	18 020	27.1
			57	89	9 900	15 100	13 000	18 200	28.5
2.1	1.0	0.8	69	108	11 600	17 800	14 330	20 530	30
			79	122	12 400	19 000	14 780	21 380	31
			86	133	13 000	20 000	15 060	22 060	31.6
			95	147	14 000	21 400	15 900	23 300	31.7
			95	147	12 500	19 200	13 890	20 590	32.8
			116	180	16 600	25 400	17 620	26 420	33.3

The diagram is not of general application and has to be drawn for each concrete case.

The value of the result nonetheless remains unaffected. It can be defined as general and very significative as it concerns applications in which the investigation to get the minimum weight is of great importance with the limits of axle loading usually imposed on shunting locomotives, especially within works boundaries.

3. EXAMPLE OF APPLICATION.

To cover the work of sorting and shunting wagons inside an industrial establishment : the basic data are as follows :

— Daily hours of work : H = 10.

— Volume of traffic handled during the H hours : T*vr* = 4 000 TKVR.

— Weight of the average rake : Q = 100 t.

— Weight of the maximum rake : Q_{max} = 150 t.

— Average unit resistance : r = 5 kg/t.

— Maximum unit resistance : r_{max} = 30 kg/t.

— Coefficient of adhesion : f = 1/5.

— Minimum weight of the locomotive, supposing it being all adhesive :

$$P = \frac{r_{max} \cdot Q_{max}}{1\,000 \cdot f} = 22.5 \text{ t.}$$

First of all the unit cost of working $C_1 \ldots . C_4$ for the four types of locomotive quoted under point 1 is determined.

As the power developed at the tread will reach (see point 1) 0.0185 · 4 000 = 74 ch./h. in considering the specific accumulation of energy in the case of : fireless locomotive : compressed air locomotive; electric accumulator locomotive (see Fig. 1), the respective weights of of the accumulators when charged are :

$$P'_a = \frac{74}{4.2} = 17.6 \text{ t.}; \quad P''_a = \frac{74}{1.9} = 39 \text{ t.};$$

$$P'''_a = \frac{74}{25} \simeq 3 \text{ t.}$$

The charging pressures are taken as : fireless locomotive 25 to 60 atm.; compressed air locomotive 70 to 120 atm. The compressed air locomotive would be too heavy. It would be necessary therefore to reduce its output to 2 000 TKVR by increasing the number of charges per 10 hours to 2, so that :

$$P''_a \simeq 20 \text{ t.}$$

If we refer to existing designs the weights of the locomotives will be :

$$P' = 38 \text{ t.}; \quad P'' = 40 \text{ t.}; \quad P''' = 25 \text{ t.},$$

all over the minimum laid down of 22.5 t and thus after taking into account as well the gradual consumption of the fluid in the case of fireless and compressed air locomotives.

The weight of an ordinary shunting locomotive will be :

$$P = 45 \text{ t.}$$

Consequently the average transport efficiency in the four cases mentioned will be respectively :

$$\eta_t = \frac{Q}{P + Q} = \frac{100}{45 + 100} = 0.69;$$

$$\eta'_t = 0.725; \quad \eta''_t = 0.713; \quad \eta'''_t = 0.80.$$

Let us now find the values of the terms

in the expression of $C_1 \ldots C_4$ whilst remembering that :

— the prices in force during the last pre-war period have been used as basis;

— the usual steam locomotive has a boiler pressure of 12 kg/cm² and is superheated. Grate area = 1.8 m²;

— the fireless locomotive has a forged reservoir with a charging pressure of 70 kg/cm² and has a superheater;

— the stationary plant for producing the steam used to charge up burns fuel of poor quality (xyloid lignite);

— in the four cases 2 locomotives are used one in service and one under pressure spare.

As the result we get :

q_v = 16 kg/ch.-h.; q'_v = 16 kg/ch.-h.; i_v = 710 cal./kg; i'_v = 700 cal./kg; $i_a = i'_a$ = 15 cal./kg; P_{ci} = 7 500 cal./kg; P'_{ci} = 4 000 cal./kg; η_c = 0.7; η'_c = 0.8; C = 300 lire/T.; C' = 150 lire/T.; G = 1.8 m²; H = 10 h.; T_{vr} = 4 000 TKVR; η_t = 0.69; η'_t = 0.725; η''_t = 0.713; η'''_t = 0.8; P_f = 5 lire/h.; P_m = 6 lire/h.

As regards the capital $S_c \ldots S'''_c$, the following data will be used with a rate of interest on the capital of 5 %.

Type of locomotive	*Cost price of the two locomotives* Lire	*Cost price of the accessory plant* Lire	*Total cost* Lire	*Period amortisation* Years	$S_c \ldots S'''_c$ Lire/year
Normal	900 000	40 000	940 000	20	75 400
Fireless	800 000	300 000 (1) 90 000 (2)	1 100 000 890 000	20	88 100 71 300
Compressed air. . . .	700 000	120 000	820 000	20	65 700
Lead battery accumulator locomotive. . .	600 000	60 000	660 000	12 (3)	74 000

(1) In the case of a small steam-producing plant being installed to charge the reservoir.
(2) To meet the case when this plant is already installed.
(3) The result of an average to take into account the life of the batteries.

In addition :

q_a = 22.5 kg/ch.-h.; η = 0.65; p_a = 120 kg/cm²; C'' = 0.20 L./kWh.

η_m = 0.7; η_e = 0.75.

Substituting in the expressions (1) :

$C_1 = 0.1352$; $C_2 = \begin{cases} 0.0886 \\ 0.0771 \end{cases}$

$C_3 = 0.0792$; $C_4 = 0.1307$

This is why the fireless locomotive in the above mentioned case occupies a favourable position if a steam raising plant already exists.

The dimensions of the reservoir of the fireless locomotive are calculated as follows :

From Fig. 5, in relation with the value $P_1 = 71$ atm. of charging pressure results a value of $x^v_r = 0.305$ kg/kg and from Fig. 7, for a drop of pressure from $p_1 = 71$ atm., to $p_2 = 6$ atm., an average specific steam consumption when superheated $\sigma_e^m = 16.2$ kg/ch.-h. eff.

On the base of an output of A = 4 000 TKVR the initial weight of the water charged becomes from formula (10) :

$$P_1 = \frac{0.0185 \cdot 4\,000 \cdot 16.2}{0.305} = 3\,930 \text{ kgr.}$$

and the volume $V_s m^3$ of the reservoir from formula (11) :

$$V_s = 6/5 \cdot 3\,930 \cdot 0.00136 = 6.42 \text{ m}^3.$$

Once the length of the reservoir is fixed at $L_s = 5$ m by formula (12) we get the diameter :

$$D_s = 2\sqrt{\frac{6.42}{5.\pi}} = 1.27 \text{ m.}$$

and by formula (13) a thickness S mm using steel of tensile R = 42 kg/mm² (26.67 t. per sq. inch.) :

$$S = \frac{70 \cdot 1\,000 \cdot 1.27 \cdot 2.5}{200 \cdot 42 \cdot 1} = 27 \text{ mm.}$$

It is as well as for the same value of V_s to find the minimum weight P_s of the reservoir in terms of L_s relatively to the transverse dimensions the reservoir can be given within the loading gauge and with an insulating covering 10 cm (3 15/16″) thick.

The investigation into the minimum weight in terms of the charging pressure will be done by following the principles set out at the end of point 2.

4. CONCLUSIONS.

From this exposition, it is clear that the fireless locomotive can have advantages from the aspect of economy and reliability of working when compared with the normal steam locomotive, compressed air locomotive or accumulator locomotive.

We have shown how to carry out an investigation in this sense and have given the bases of a scheme.

***

APPENDIX.

Data on the origin of the formulae (1).

a) *Expression of* C_1.

*a*1) The first term of the second member represents the cost price of fuel for one TKVR. Actually

$0.0185 = \frac{5 \times 1\,000}{3\,600 \times 75}$ ch.-h. used at the wheel tread to haul 1 ton over 1 km on the hypothesis of an average unit resistance of 5 kg/tonne.

$\frac{q_v (i_v - i_a)}{\eta_c}$, calories actually given to the q_v kg of steam used for 1 ch.-h.

$\frac{q_v (i_v - i_a)}{\eta_c} \cdot \frac{1}{P_{ci}}$, kg of coal used for 1 ch.-h, etc.

*a*2) The meaning of the term :

$$\frac{2}{3} \cdot \frac{30G \frac{C}{1\,000} H}{T_{vr}}$$

has been explained adequately at point 1 in considering C_1 relatively to the TKVR.

*a*3) Finally the term in brackets indi-

cating the cost of fuel for 1 TKVR has to be multiplied by $1/\eta_t$ as we are dealing with the TKVR and not TKV.

b) *Expression of* C_2.

*b*1) For C_2 the considerations of *a*) are applicable : C_2 does not include the term of point *a*2 which represents the cost of fuel lost during stops by the usual shunting locomotive.

c) *Expression of* C_3.

*c*1) The term in brackets multiplied by $1/\eta''_t$ represents the expenditure for the tractive energy of 1 TKVR. Actually $0.0185 \times q_a$ is the quantity of compressed air used for 0.0185 ch.-h.

In addition :

$$\frac{0.0223}{\eta_l} \cdot l_n \cdot p_a \quad \ldots\ldots \quad (x)$$

represents the consumption of energy in kWh to compress 1 kg of air to the absolute pressure of p_a atm.

From the formula :

$$L^{[kgm.]} = p_o^{[kgr./m^2]} \cdot v_a^{[m^3]} \cdot l_n \frac{p_a}{p_o}.$$

we deduct by taking $p_o = 1$ atm. :

$$E^{[ch.-h.]} = \frac{10\,000}{270\,000} \cdot 1 \cdot \frac{q_a^{[kgr.]}}{1\,225^{[kgr./m^3]}} \cdot l_n\, p_a$$

Making $q_a = 1$ kg and expressing the energy in kWh :

$$E^{[kWh.]} = \frac{0.736 \cdot 10\,000}{270\,000 \cdot 1\,225} \cdot l_n\, p_a$$

whence we obtain the formula (*x*).

Data relative to the formula (7).

From figure 4 between 140 and 225 atm. the two curves of the thermic capacity of the water and of the steam can be drawn according to a parabola related to the axis *y*, vertical and tangent to the parabola at its top A_1 and the axis *x* horizontal and passing through A_1.

The parameter of this parabola is :

a) $p = y_o^2/2\, x_o$, whence :

x_o, y_o are the coordinates of a point of the parabola.

This gives :

$$b)\ d\ (\alpha_v) \cdot 1 = \frac{dy}{r}$$

But from figure 4, we read :

c) $r = 2_y$,

and from the equation of the parabola :

$$y^2 = 2\ p\ x,$$

d) we have :

$$dy = \frac{p}{y} \cdot dx$$

Taking into account (*a*), (*c*), (*d*), formula (*b*) can be expressed in the form :

$$d\ (\alpha_v) = \frac{y_o{}^2 x_o}{4\ x_o y_o{}^2 x}\ dx,$$

or :

$$e) \qquad d\ (\alpha_v) = \frac{dx}{4x}$$

For a drop of the charging pressure p_1 (abscissa x_1), to the pressure of 140 atm. the limit of the two zones II and III (abscissa x_2) the integration of the formula (*e*) gives us :

$$\alpha_v = \frac{1}{4} \cdot lnx \Big]_{x_1}^{x_2}$$

$$= \frac{1}{4}\ (ln\ x_2 - ln\ x_1),$$

i. e. formula (7):

$$\alpha_v = \frac{1}{4}\left[ln\ (p_c - 140) - ln\ (p_c - p_1)\right]$$

Data relative to the formula (9).

Formula (9) represents an analytical translation of the experimental results of many locomotive tests.

If we refer to the note mentioned of Dr. A LANGROD, we can come to the conclusion that :

1. The consumption of steam σ corresponding to the absolute temperature T of the steam is related to the value σ_1 corresponding to the temperature T_1 by the expression :

$$\sigma_1 = \sigma\left(\frac{T}{T_1}\right)^2$$

2. « By means of wire drawing tests in which the steam pressure underwent wide modifications it has been noted by using the above quoted substitution that the influence of the steam pressure on the specific consumption already appeared to have been taken into consideration by the introduction of the effective admission as reference value. »

3. « Theoretical considerations show that using the effective admission as reference value, the influence of the hourly introduction of steam and of the volume swept by the piston has been taken into account. »

4. « Brought to a constant steam temperature the test results from all the locomotives investigated show that the relation between the specific steam consumption and the effective admission for a constant steam temperature corresponds to the equation of a parabola the axis of which is parallel to the direction according to which the specific steam consumption is measured. »

5. « The result of the whole of the tests is that on a diagram on which the effective admission is shown as abscissae and the specific steam consumption as ordinates, the parabola mentioned above displaces itself downwards and to the left without changing form when the number of revolutions increases. The conclusion drawn is that at constant steam temperature and with the number of revolutions increasing, the specific steam consumption varies directly as the effective admission. »

6. « If these conclusions be accepted the specific steam consumption is shown by the equation :

$$\sigma = \frac{A}{T^2} + C\left(\varepsilon - \frac{B}{T}\right)^2$$

in which the coefficients A and B become smaller in an approximately linear ratio when the number of revolutions increases, whilst C is a constant. »

Data relative to the formula (13).

The original formula of HAMBOURG is the following :

$$p \leqslant \frac{200\ R.s.z}{D_i \cdot x}$$

in which :

p, kg/cm^2, boiler pressure;

R, kg/mm^2, tensile strength of the material;

s, mm, thickness of the barrel;

z, ratio between the strength of the joint and that of the barrel plate;

D_1, mm, inside diameter of the reservoir;

x, coefficient of safety.

This formula does not take into account:

1. the non-uniform distribution of stresses in the barrel thickness;

2. the influence of the temperature in the strength of the material.

Consequently, a factor of safety x — as in Hambourg's formula, — independent of the temperature, has only an imaginary value.

On the other hand, formula (13) perfects the Hambourg formula :

— Following point (1), by using instead of the inside diameter D_1, the outside diameter D_s.

— Following point (2), by making :

$$x = x_1 \cdot x_2$$

in which :

x_1, coefficient of elastic limit;

x_2, true factor of safety.

[624 .6 (43)]

Increasing the clearance of an overbridge.

A method adopted in Germany to obtain the necessary headroom for overhead equipment.

(*The Railway Gazette, March 17, 1950.*)

To save coal and to improve operation, the German railways are electrifying the main line between Nuremberg and Regensburg in Bavaria. Conditions are particularly favourable as the stations at both ends are already electrified, and there are no major intermediate stations calling for large-scale engineering works. The line carries a considerable goods traffic and has fairly heavy gradients.

low for an electrified line. All these bridges had to be lifted.

This was not difficult with the girder bridges. In short line possessions, the bridge superstructures were lifted and placed temporarily on broad-flanged I-beams inserted between the girders and built-up ends of the abutments. This permitted road traffic to be resumed without having to await the setting of the

Girder bridge on Nuremberg-Regensburg line, raised to obtain clearance for electrification.

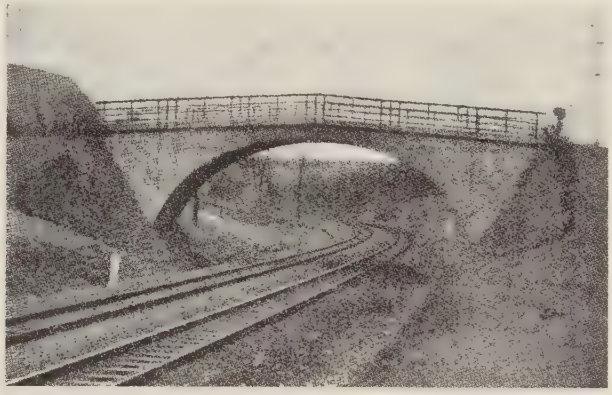
Among the most important works incidental to the electrification, is the enlargement of the fixed structure loading gauge. German regulations prescribe a minimum height of 4.80 metres for steam-operated lines and 5.50 for electrified lines with overhead transmission; for some existing bridges the requirements are reduced to 5.30. Of the 19 road overbridges on the Nuremberg-Regensburg section, 14 are too

raised concrete bearing blocks poured between the ends of the abutments.

With the arched overbridges, however, the required clearance was normally available at the crown, but not at the haunches of the arch. A complete reconstruction of these bridges would have been costly. The tackling of the problem is described in *Der Eisenbahnbau*, of September, 1949. Professor Schaechterle, of Stuttgart,

and prominent firm of building contractors conceived the idea, independently and simultaneously, of gaining the required headroom by replacing the central part of the arch by a rigid horizontal frame

tically. It was decided, however, to experiment with one bridge, and it was found that its appearance is not so bad as to justify rejection of this economic solution, which is regarded as a « utility operation ».



Arched overbridge with inadequate clearance for overhead electrification, before reconstruction.

Arch with crown replaced by a reinforced concrete frame, giving the necessary clearance.

of reinforced concrete which could be regarded as an enlarged keystone, absorbing the lateral thrust of the arch. It is admitted that the interruption of the arch line by the « alien » body of horizontal frame is not entirely satisfactory aesthe-

For the statical calculations of the frame, two extreme cases were assumed, In the first, the frame was calculated, in accordance with the theory of elasticity, as part of the arch where the resultant of forces passes outside the arch. In the second, the frame

was regarded as a two-hinged frame with hinges at the centres of the supporting vault faces. The steel reinforcement was designed so as to meet whichever case was less favourable.

There was no difficulty in carrying out the work. First, the backing in the centre was removed as far as necessary and the remainder tapped by sills of reinforced concrete so as to ensure a uniform distribution of the vault thrust over the entire surface. The sills were dovetailed with the intact part of the arching. When this was done, slots were cut into the arch ring proper and three broad-flanged I-beams 36 cm in height wedged between the transverse stiffeners, so that the vault thrust was transferred to them. Then, the rest of the crown section was demolished.

The shadow of the catenary protection masks the less æsthetic outline of the rebuilt arch.

The I-beams were thus used not only for the transmission of the vault thrust but also to carry, first, the protective planking during the demolition, and, later, the shuttering for the concrete frame. During the concreting, slots had to be left open through which the I-beams could be removed.

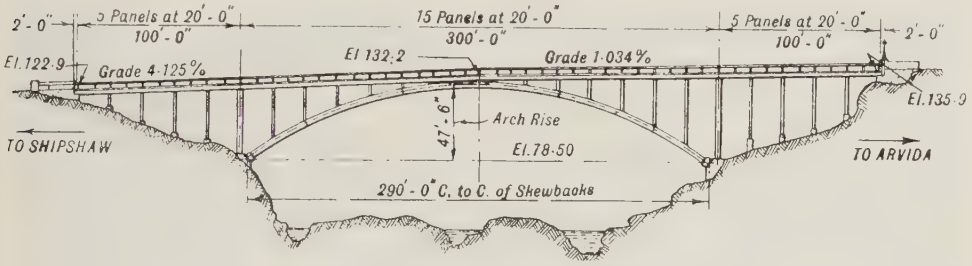
[624 .62 (71)]

An aluminium highway bridge.

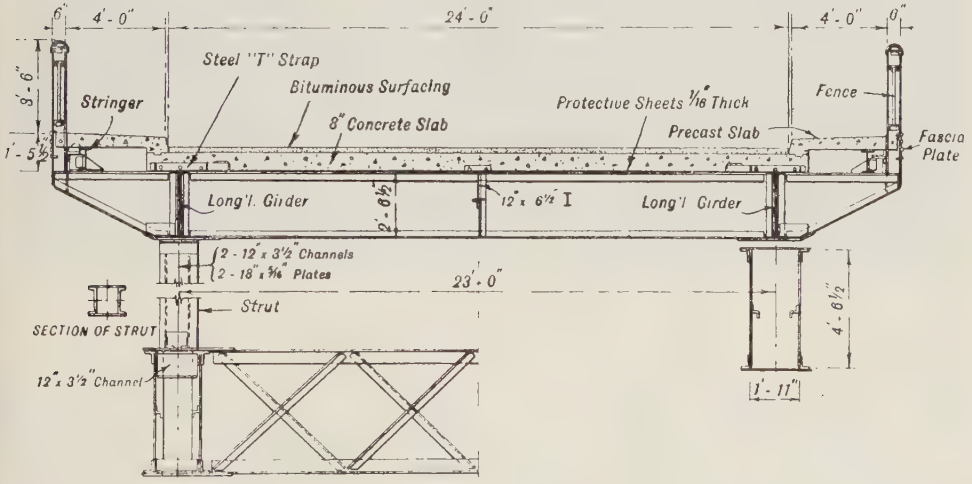
(*The Engineer, February, 24, 1950.*)

An aluminium highway bridge, said to be the first on the American continent, is at the present time approaching completion in the municipality of Arvida, in the Province of Quebec, Canada. The bridge spans the Saguenay River in the immediate vicinity of Shipshaw power house No. 2, a 1 million HP hydro-electric plant supplying power to the Arvida aluminium works of the Aluminum Company of Canada, Ltd.

In 1943, at the request of the city of Arvida, the general engineering department of the Aluminum Company of Canada began to make preliminary studies of the proposed bridge. On account of the



Arvida aluminium highway bridge.



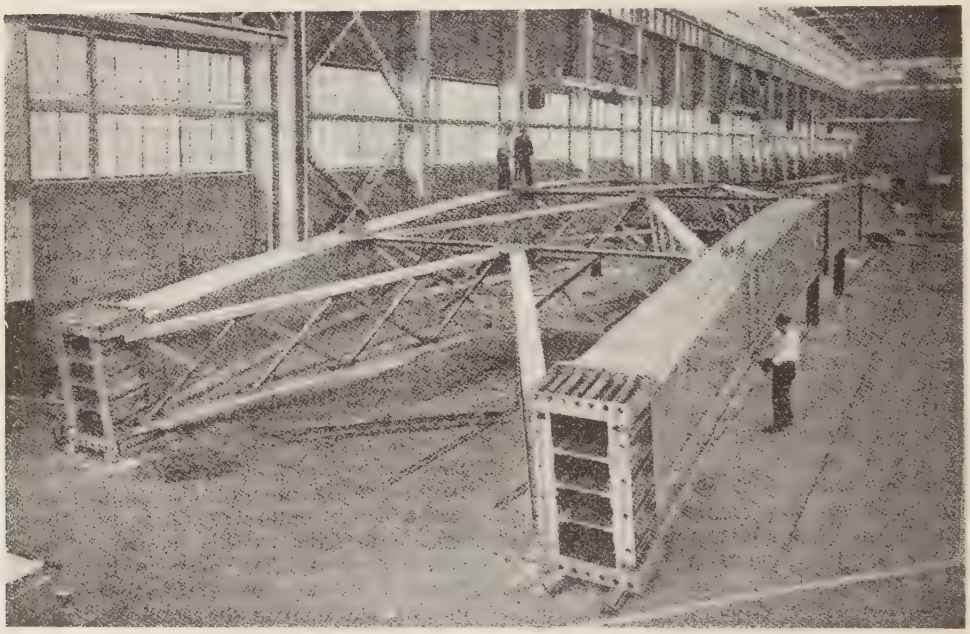
Typical section through bridge.

natural beauty of the site and the intention to develop the south shore opposite the power-house into a park, considerable thought was given to the appearance of the structure. An arched bridge was chosen as the one most appropriate to the topography of the site, its use being justified technically by the excellent rock formations on the shores capable of taking the thrust. Two alternative designs were considered, in aluminium and in steel, and the aluminium bridge was eventually adopted.

The main span of the bridge covers a distance of 290 ft. and consists of two parabolic arch ribs, each with a central rise of 47 ft. 6 in. The two ribs are spaced at 23 ft. centres, each being a box girder, braced together with a K system of lattice girders; they have encastré supports. The roadway is carried on box struts at 20 ft. centres, which are not braced, except for the ones at the skewbacks, which are of heavier construction and are braced together with horizontal struts, there being three struts above each shewback, to take the lateral wind reaction from the deck. There are five 20 ft. continuous girder approach spans at each end of the bridge, the total length between the back walls of the abutments being 504 ft. An elevation of the complete structure is shown on p. 45.

The floor system consists of two lines of longitudinal girders, continuous from end to end and supported by the struts, and of floor beams of the same depth as the girders and framing into them at panel points and at midspan. The floor beams are thus spaced 10 ft. apart and carry a pavement bracket at each end. Longitudinal stringers on the centre line of the bridge span between the floor beams, and two lines of pavement stringers rest on the pavement brackets.

The roadway is 24 ft. wide between



Fabrication of main chord.

kerbs and is an 8 in. poured-in-place continuous concrete slab, reinforced in two directions. There is no crown in the roadway and the bituminous wearing surface is 2 1/2 in. thick throughout. There are two 4 ft. pavements of precast concrete construction, the precast units being 5 ft. long. The slab thickness varies from 6 1/2 in. at the outer edge to 5 1/2 in. near the kerb.

The bridge deck slopes down from the south end, the gradient being 1.034 per cent over the south approach and 4.125 per cent over the north approach, with a joining vertical curve over the arch span. Finger plate expansion joints are provided in the roadway at both ends of the bridge, with drainage troughs underneath. There are no intermediate drainage scuppers.

Design.

The bridge was designed for an average dead load of 4 840 lb. per lineal foot of bridge over the arch span and 4 420 lb. per lineal foot on the approaches. The live load on the roadway was taken as 80 lb. per square foot and on the pavement as 40 lb. per quare foot.

The structure was also checked for an alternative live load of a 62-ton trailer, pulled by an 18-ton tractor. It was assumed that this load would travel on the centre line of the bridge at a slow speed, producing no impact. Apart from this case, an impact allowance of 30 per cent was made.

Wind loading was considered as a lateral force of 30 lb. per quare foot on one and a half times the projected area of the structure, plus 200 lb. per lineal foot of bridge applied 7 ft. above the roadway, or 50 lb. per square foot on one and a half times the projected area of the unloaded structure. The structure was also designed to withstand stresses resulting from a temperature variation of 140 deg. Fah. from — 40 deg. to + 100 deg.

Owing to high working stresses and low modulus of elasticity of the material the deflections of members were of some consequence, and every effort was made to keep them to a minimum. For this reason, where no give at the supports could be expected, it was deemed advisable to use seat connections in preference to ordinary connection angles. It was feared that after many repeated loadings, because of the comparatively low ductility of the material, cracks might develop in the angles. The floor system being completely integrated with the concrete deck, the temperature effects were important.

Floor system.

The continuous longitudinal girders are 2 ft. 6 1/2 in. back to back of angles, built up of 30 in. by 5/16 in. web plates and four 3 1/2 in. by 3 1/2 in. by 3/8 in. flange angles, except in the end panels, where the angles are 1/2 in. thick. The temperature forces were assumed to act at mid-depth of the floor slab and were transmitted into the girders wich rigid brackets.

The floor beams are of the same depth as the longitudinal girders. The web is also 30 in. by 5/16 in. plate, but the flanges are made 3 1/2 in. by 3 1/2 in. by 1/2 in. angles. The pavement brackets are cantilevered at both ends of each floor beam and are of the full floor beam depth at their inner ends. The top flange straps are made of steel tees and are connected to the aluminium with galvanised steel bolts.

The handrail was designed for considerable lateral forces. The handrail posts are 6 in. by 6 in. H beams. To prevent temperature stresses and possible distortion, the longitudinal members of the handrail and the fascia are connected to the handrail posts by means of bolts in slotted holes. The floor is also braced with single-angle diagonal bracing in the plane of the bottom flanges of the longitudinal girders and floor beams.

The floor system is carried on three sliding plate bearings at each abutment : two under the ends of the longitudinal girders and one in the middle of the end floor beam. The sliding surfaces are rolled bronze on steel, the bronze plate being connected to the aluminium member above with galvanised steel bolts and separated from it with a sheet of insulating material.

The sliding surfaces are tongued and gooved and the steel bed-plate is securely anchored to the concrete.

Arch ribs.

Except for the end panels, the arch ribs are made of the same material throughout and are built up of two 54 in. by 9/16 in. web plates, 1 ft. 9 7/8 in. inside to inside, four 6 in. by 4 in. by 1/2 in. angles 4 ft. 6 1/2 in. back to back, turned out, and two 32 in. by 3/4 in. in cover plates. The gross area is 127.95 square inches. In the end panels the cover plates are 32 in. by 1 in. The general arrangement is shown in the typical section reproduced on page 45.

The web plates are stiffened at mid-height with longitudinal 4 in. by 3 1/4 in. Z bars running between transverse stiffener frames which are spaced about 5 1/2 ft. apart and consist of 4 in. by 4 in. by 3/8 in. angles on the cover plates riveted at the corners to form a rigid frame. There are two such frames under each post, 1 ft. apart, and, the post being placed centrally on the rib, the top horizontal stiffeners are replaced with 12 in. channels, which transmit the load to the rib web plates.

The ribs are spliced at each post, except the two nearest the centre, the ribs being symmetrical about the crown. There are field splices at the crown and at the second and fifth posts from the skewback, with shop splices at the remaining posts. The rib sections are faced for bearing. The splices were designed for 50 per cent of compression capacity of the rib and checked for maximum possible tension increased by 50 per cent. The bracing between the ribs consists of struts at the panel points and of diagonals, forming a K system. Both are almost the full rib depth and are of latticed girder construction, the chords of struts being made of T's, cut from 12 in. by 6 1/2 in. I beams, and those of the diagonals of 10 in. channels. The web system consists of double intersectional diagonals, without « verticals », all diagonals being of one 3 in. by 3 in. by 5/16 in. angle.

The bracing is connected to the ribs with lateral plates and bevelled fills are provided to take care of a sudden change of inclination of the plane of bracing, as compared with the smooth curve of the ribs.

The bases of the ribs each rest on a steel bedplate, 6 ft. 8 in. by 4 ft. and are each anchored with twenty-two 2 in. diameter steel bolts with seven bolts for each flange and four for each web.

The bolts at their lower ends are welded to a steel frame to ensure their accurate spacing and setting prior to pouring of concrete. The completed base detail is concealed with an alloy sheet casing.

Despite the fact that the span of the arch ribs is comparatively short, the effect of the rib deflections was investigated, because of the low modulus of elasticity of the material. It was considered reasonable to make an overall allowance for the effect of rib deflection by means of a 10 per cent reduction in the permissible stresses in the rib calculated in the usual manner.

Riveting.

The structure is being riveted with cold-driven aluminium alloy rivets, 51/64 in. diameter. Shop rivets, where possible, are pressure driven, while all field rivets, as well as the shop rivets inaccessible to the riveting machine, are driven with a heavy pneumatic riveting gun. Originally the field connections were to have been bolted, as it was considered impracticable to drive cold aluminium rivets of this size with a gun. However, a programme of rivet testing was carried out, the result of which was the development of a satisfactory technique of driving cold rivets with a gun. A new type of driven rivet head was also developed.

Although aluminium alloys have excellent weather-resisting qualities, where surfaces are in contact with other metals, or even with each other, in presence of moisture there is some danger of galvanic corrosion, unless proper precautions are taken. Even a thin layer of some neutral

material, such as bituminous paint, is considered adequate to prevent it. Consequently all aluminium surfaces in contact will be covered with a coat of such paint, containing 5 per cent of zinc chromate. In the case of the connection to the bronze sliding plates at the ends of the bridge this precaution was thought insufficient owing to possible accumulation of dirt, and a sheet of fibrous insulating material, 1/8 in. thick, was provided between the aluminium and the bronze.

When completed, the bridge will be thoroughly cleaned, but will not be painted. Nevertheless, access will be provided to all parts of the structure, so that if desired it can be painted at some future date.

The Aluminum Company of Canada carried out the preliminary work for the design and siting of the Arvida bridge. It is being fabricated and constructed by the Dominion Bridge Company, Ltd., which made the final design of the aluminium structure. It is believed that there are only two other aluminium bridge spans in existence at the present time. One of them is a railway bridge at Massena, New York, which has a 100 ft. aluminium girder, and the other the Hendon Dock bridge across the River Wear at Sunderland. The latter is a double-leaf bascule bridge, which spans a waterway of 90 ft. width; it was described in *The Engineer*, December, 3, 1948.

NEW BOOKS AND PUBLICATIONS.

[**385** (09 (5+6)]

Les Chemins de fer de la France d'Outre-Mer. *(French Overseas Railways).* — Special number dated 14th May, 1949, of the weekly review : *Marchés Coloniaux du Monde.* — One volume (9 1/2 × 12 1/2 in.) of 100 pages with numerous illustrations and maps. — 1949, Paris (VIII[e]), *Marchés Coloniaux du Monde*, 190, boulevard Haussmann. (Price : France, 300 French francs; abroad, 350 French francs.)

In publishing this special issue, the review « Marchés Coloniaux du Monde » is not going outside its essential sphere, since if the Railways were the first lines of penetration in French territory overseas, they still constitute the principal if not the only method of transporting the products of the colonies towards the ports. Moreover the arrival of the Railway in districts till then only served by rather uncertain waterways has often led to a great increase in the importation of goods.

This book consists of a series of monographs by authors actively concerned in the management of the undertakings in question. They cover first of all the Railways of French West Africa : the Dakar-Niger, the Conakry-Niger, the Ivory Coast Railways, the Benin-Niger, the Togo Railways, Cameroons Railways, Congo Ocean, and then the Madagascar Railways, and finally the Indo-China Railways.

The most interesting part of these notes is that giving the history of the building of these lines. From the first surveys, which sometimes go back far into the nineteenth century, the promotors came up against political, administrative and financial obstacles. As for the work itself, this was affected by the climate, lack of security, uncertainty of the water supply, and repercussions of the war. The technical characteristics were inspired by the need for keeping down the first cost, and the mountainous nature of much of the country traversed.

Detailed information is given about the organisation of the trains, the operating methods, the traction and rolling stock, the amount of traffic, the products carried, and the operating results.

As prospects improve, certain lines have been or will be considerably modified in order to increase their output and decrease operating costs. The work in question consists of strengthening the superstructure and improving the profile and layout.

Amongst the illustrations, mention must be made of the very clear black and white maps showing for each Railway system the layout of the lines together with the water courses and mountain ranges. These were prepared by M. M. Lartilleux, who drew them for the third volume of his Universal Geography of Transport.

The monographs on the different Railways are preceeded by studies of general interest, for example first of all the « Organisation of the Railways in French Overseas Territory », « Stages in the construction of French Overseas Railways and modernisation schemes », then the « Modernisation of the Rolling Stock » consisting of a general study, Railcars, Rolling stock and up-to-date standards for vehicles, and Diesel Traction.

Colonial rolling stock is able to profit by the improvements made on the Railways of the mother country. An example of the closest liaison and collaboration between the colonial Railways and those of the mother country is to be found in another note on the « Organisation and working of the purchasing department of the Central Railway Office ».

This publication, crammed with characteristic facts and full of information, is a well founded tribute to one of the most remarkable works of the French colonial empire.

E. M.

[**385** 113 (59)]

SANDERS (J. O.), C. M. C., M. Inst. T., A. M. Inst. C. E., General Manager, Malayan Railways. — **Malayan Railway Report for the year 1948.** — One brochure (7 7/8 × 13 3/4 in.), of 68 pages, illustrated. — 1948, Kuala Lumpur Government Press. (Price : 4 s. 6 d.)

The Malayan Union Railway serves the peninsula of Malacca divided from the Island of Sumatra on the west by the strait of Malacca and joined to the continent of Asia by an isthmus which is an extension of Siamese territory.

From Singapore the main line runs towards the north-west and then keeps close to the western coast, branch lines running to the ports. About 140 miles from the starting point, another line branches off towards the north which reaches the China Sea coast at the Siamese frontier. This last line was destroyed to a great extent by the Japanese.

The development of these lines which was 1 332 miles in 1941 fell to 792 miles by the end of 1946. It had been restored to 809.5 miles by the end of 1947.

The permanent way is one metre gauge, with Vignole rails fastened directly to the sleepers. The maximum gradient is 10 per 1 000, except on a short section where it is 12.5 per 1 000. On the main line 80 lbs. rails are used. In view of the branch lines there are various sections : 80, 60 and 46.5 lbs. The sleepers are made of native hardwoods and not impregnated. They are 10 by 5 in. square and 6 ft. 6 in. long. There are 2 112 per mile.

The importance of the goods traffic can be appreciated by the tonnage carried which amounted to 1 388 932 tons in 1947, i. e. 1 065 tons per km of line.

On the other hand, if the transport distances are taken into account we get 167 187 110 ton-miles, i. e. 20 000 ton-km per kilometre of line.

The report gives very detailed information about the financial results, the evolution of the passenger and goods traffic, and the train services. Here as in all the countries ravaged by the war, it has not yet been possible to return to normal conditions. In particular the goods traffic suffers from the shortage of wagons. The financial situation is also unfavourably affected by the competition of air and road transport. On the other hand, it has not been possible to increase the rates proportionately to the costs, so that all the Railway can do is to try and increase the volume of traffic.

The activity of the ports, the locomotive mileage, traction installations, permanent way and bridges, are the titles of important chapters. In the last named can be seen the efforts made by the management to restore to some extent the lines that were destroyed or badly maintained during the war and the important bridges.

Mention must also be made of the signalling and telecommunications, the accountancy, and, the final chapter, all the steps taken to benefit the staff.

The arrangement of the report which is a remarkable document by reason of its clarity and the value of the information supplied, gives the reader the agreeable impression of getting a definite idea of the Railway. It also makes it possible to judge of the very great possibilities of the metre gauge in colonial countries.

E. M.

[537]

PUTMAN (F.), Ingénieur des Arts et Métiers (E. C. A. M.). — **L'A. B. C. de l'Electronique.** *(The A. B. C. of Electronics)*. — One volume (8 1/4 × 10 1/2 in.) of 140 pages, abundantly illustrated. — 1949, Brussels, Société d'Electricité et de Mécanique (S. E. M.), 54, chaussée de Charleroi. (Price : 125 Belgian francs).

It would no longer be accurate to state that electronics have opened up vast perspectives for industry. Such a statement would be retrogressive in view of the present state of affairs.

Current rectifiers are widely used. Aluminium and magnesium metallurgy makes extensive use of them. Electronic circuits are an essential part in the working of many electric circuits. Induction and dielectric heating have been made possible by the creation of very high frequencies. We only mention these facts in passing, together wih the amazing performance of the electronic calculating machines. One of them can calculate the factors in the trajectory of a shell faster than the shell can travel.

Electronics, the mechanics of the electron, is the result of the immense progress made during the last fifty years by the physical sciences. Their starting point was the discovery of the discontinuous structure of the electric load. The imagination and audacity of the research workers led to the birth of theories which have made it possible to obtain an accurate idea of the architecture of the atomic world. A preeminent part was played by the idea of relativity and undulatory mechanics. Quite recently there has been considerable progress in the techniques of physics. Experimenters have been able to isolate the electron and measure its weight, mass, and radius, which characteristics are expressed in c. g. s. units by large numbers of decimals.

The object of this publication is not purely scientific. The reader desirous of extending his knowledge can consult the works published by many scientists who have endeavoured to solve the mystery of the constitution of matter. It is enough to read a modest volume only intended to give a general view of atomic physics to appreciate the extent of this field.

The author is merely concerned with the presentation and working of apparatus whose functioning is based on the liberation and movements of electrons. He describes them briefly with the aid of lucid diagrammatic drawings according to a methodical classification. He characterises them according to the voltage and output, and gives their chief utilisations.

In the second part, he reviews the industrial applications. The plans of connections accompanying the report make it easy to follow the working of the phenonema described.

The essential property of electronic valves is their capacity to modify rapidly any changes in the electric current. This is made use of in the ingenious Thy-Mo-Trol equipment, Thyrotron Motor Control (electronic control of motors) which makes it possible to run a direct current motor from an alternating current supply and closely controls its running.

This book will deeply interest all those dealing with electric installations by showing them the many purposes for which electronic valves can be used.

E. M.

MONTHLY BIBLIOGRAPHY OF RAILWAYS[1]

PUBLISHED UNDER THE SUPERVISION OF

P. GHILAIN,

General Secretary of the Permanent Commission of the International Railway Congress Association.

(JANUARY 1951)

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[**016.** 385. (05]

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1949 **656** .24 (42)
ulletin de l'Union intern. des Ch. de fer, septembre-octobre, p. 272.
Méthodes employées par les Chemins de fer britanques pour prévenir les **réclamations.** (4 500 mots.)

1949 **656** .225 (45)
ulletin de l'Union intern. des Ch. de fer, septembre-octobre, p. 277.
CELLI (S.). — Les **transports de denrées périssables** en rovenance d'Italie. (2 500 mots & fig.)

1949 **656**
ulletin de l'Union intern. des Ch. de fer, septembre-octobre, p. 283.
Le **chemin de fer et l'avion** en trafic international. 2 000 mots & tableaux).

1949 **656** (494)
ulletin de l'Union intern. des Ch. de fer, septembre-octobre, p. 287.
DREYER (G.). — Les **nouveaux locaux de la Swissair** ans les gares C. F. F. (1 500 mots & tableaux.)

1949 **656** .223 .2
ulletin de l'Union intern. des Ch. de fer, septembre-octobre, p. 292.
Détermination du **pourcentage des parcours des wagons des.** (1 600 mots & fig.)

1949 **385** .114
ulletin de l'Union intern. des Ch. de fer, novembre, p. 322.
FIOC (A.). — Les principes du calcul des **prix de evient** dans les chemins de fer. (7 000 mots et tableaux.)

1949 **656** .211 .5 (494)
ulletin de l'Union intern. des Ch. de fer, novembre, p. 339.
PETITAT (P.). — **Organisation moderne des recettes oyageurs** en Suisse. (5 000 mots & fig.)

1949 **656** .225 & **656** .261
ulletin de l'Union intern. des Ch. de fer, novembre, p. 352.
Les **containers en trafic international.** (7 000 mots.)

1949 **656** .1
ulletin de l'Union intern. des Ch. de fer, novembre, p. 370.
La nouvelle **convention internationale des transports utiers.** (2 500 mots.)

Notre Métier. (Paris.)

1949 **385**
otre Métier, 5 décembre, p. 6.
TISSIER (P.). — Le **Chemin de fer doit-il disparaître?** (5 000 mots & fig.)

1949 **624** (44)
Notre Métier, 12 décembre, p. 3.
Grands viaducs métalliques. (2 000 mots & fig.)

1949 **621** .431 .72
Notre Métier, 19 décembre, p. 3.
L'**Autorail « Budd ».** (1 500 mots & fig.)

1950 **621** .132 .8 (44)
Notre Métier, (N° spécial), p. 3.
VILAIN (L.). — Les **locomotives françaises semi-articulées système Mallet compound à 4 cylindres** des réseaux à voie métrique. (1 500 mots & fig.)

1950 **656** .254
Notre Métier, 16 janvier, p. 6
Nouvelles applications des **liaisons radiotéléphoniques** au chemin de fer. (1 000 mots & fig.)

1950 **656** .257 (44)
Notre Métier, 20 février, p. 6.
Mise en service du **poste électrique d'itinéraires** à Montereau. (1 500 mots & fig.)

1950 **621** .431 .72 (65)
Notre Métier, 17 avril, p. 6.
MACHEFERT-TASSIN (Y.). — La **traction Diesel** en Algérie. (2 000 mots & fig.)

1950 **621** .431 .72 (44)
Notre Métier, 22 mai, p. 3.
Les **autorails 150 ch** type S. N. C. F. (500 mots & fig.)

Revue générale des Chemins de fer. (Paris.)

1949 **656** .254 (44)
Revue générale des Chemins de fer, novembre, p. 481.
GAILLARD (P.). — Les **câbles téléphoniques** de la ligne de Paris à Lyon. (10 000 mots & fig.)

1949 **621** .132 .3 (44)
Revue générale des Chemins de fer, novembre, p. 507.
Améliorations des locomotives Mikado à simple expansion, 2 cylindres et surchauffe, de la Région de l'Ouest de la S. N. C. F.
CHAPELON (A.). — **Exposé des principes.** (1 500 mots.)
PLU & FOUSSARD (L.). — **Etude et réalisation d'un prototype.** (2 500 mots & fig.)

1949 **621** .335 (44)
Revue générale des Chemins de fer, novembre, p. 518.
La **locomotive électrique** prototype CC 6051. (700 mots & fig.)

1949 **621** .431 .72 (44)
Revue générale des Chemins de fer, décembre, p. 529.
TOURNEUR. — Les **locotracteurs et locomotives Diesel de manoeuvres** de la S. N. C. F. (1 600 mots.)

1949 **621** .431 .72 (44)
Revue générale des Chemins de fer, décembre, p. 531.
BERNARD. — Les **locotracteurs unifiés** de 32 tonnes, 150 ch, série Y 6200 de la S. N. C. F. (5 000 mots & fig.)

1949 **624** .32 (44)
Revue générale des Chemins de fer, décembre, p. 539.
MAURY. — La **reconstruction du pont** de Roppenheim. (3 500 mots & fig.)

1949 **625** .143 .5
Revue générale des Chemins de fer, décembre, p. 550.
SONNEVILLE (R.). — **Essais d'endurance de quelques attaches de rails.** (6 000 mots & fig.)

1949 **625** .143 .2
Revue générale des Chemins de fer, décembre, p. 560.
Le **rail en acier Thomas** sur le Réseau de la S. N. C. F. (6 000 mots.)

In German.

Der Eisenbahnbau. (Frankfurt-Main.)

1949 **656** .213
Der Eisenbahnbau, Dezember, S. 265.
THIEMER (E.) & LUCHTERHANDT (H.). — Die **Wirtschaftlichkeit der Gleisanschlüsse.** (3 000 Wörter.)

1949 **624**
Der Eisenbahnbau, Dezember, S. 275.
GIEHRACH (U.). — **Das Heben von Brücken.** (4 500 Wörter & Abb.)

1950 **624** .63 (44)
Der Eisenbahnbau, Januar, S. 9.
BATJER (F.) & NEUFFER (H.). — **Wiederaufbau der massiven Eisenbahnbrücke** bei Unterrieden über die Werra. (3 000 Wörter & Abb.)

1950 **625** .143 .3
Der Eisenbahnbau, Januar, S. 15.
KALPERS (H.). — Über die **autogene Oberflächenhärtung von Schienen.** (1 000 Wörter & Abb.)

1950 **624** (43)
Der Eisenbahnbau, Februar, S. 25.
JESSBERGER (L.). — Der **Verbundträger.** (2 500 Wörter & Abb.)

1950 **625** .144 .4
Der Eisenbahnbau, Februar, S. 34.
ZINSSER (E.). — **Maschinelles Verdübeln der Schwellen** mit Schlitzdübeln im Betriebsgleis. (1 500 Wörter & Abb.)

Signal und Draht. (Frankfurt a/Main.)

1949 **656** .25
Signal und Draht, November, S. 113.
SCHMITZ (W.). — Neue **Schaltdarstellungen für Fernmelde- und Signalanlagen.** (3 000 Wörter & Abb.)

1949 **656** .25
Signal und Draht, Dezember, S. 125.
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1949 **656** .25
Signal und Draht, Dezember, S. 132 und S. 134.
DUENSING (W.). — Aufarbeitung und Einbau von **mechanischen Stellwerkseinrichtungen** durch die Deutsche Bundesbahn.
BARZ (E.). — Aufarbeitung und Einbau von **elektr Stellwerkseinrichtungen** durch die Deutsche Bundesbahn (4 000 Wörter.)

1950 **656** .254 (73
Signal und Draht, Februar, S. 17.
WOLF (O.). — **Centralized Traffic Control Fernstellwerk erhöht die Streckenleistung** Amerikanischer Bahnen (5 000 Wörter & Abb.)

1950 **656** .25
Signal und Draht, März, S. 36.
CHAUSSETTE (G.). — Die **Wirtschaftlichkeit der Signalanlagen bei der Unfallverhütung und Beschleunigung des Eisenbahnbetriebes.** (2 000 Wörter.)

1950 **656** .25
Signal und Draht, März, S. 40.
SASSE (Dr. Ing. H.). — Die **Wirtschaftlichkeit der neuen Signaltechnik.** (3 000 Wörter.)

In English.

The Engineer. (London.)

1949 **625** .616 (73
The Engineer, Oct. 21, p. 450.
HOWARD (R.). — American **tramcar** developments (2 000 words & fig.)

1949 **621** .392 & **625**
The Engineer, Oct. 28, p. 501.
BULLEID (O. V. S.). — **Welding and railway rolling stock.** (600 words.)

1949 **656** .25
The Engineer, Oct. 28, p. 502.
V. H. F. radio equipment for railways and heavy industries. (800 words & fig.)

1949 **62f** .33 (42
The Engineer, Dec. 2, p. 640.
Power supply for the Liverpool-Southport electric lines (3 000 words & fig.)

1949 **621** .132 .1 (42) & **656** .222 .1 (42
The Engineer, Nov. 4, p. 515; Nov. 11, p. 543; Nov. 25 p. 600.
NOCK (O. S.). — **Present-day locomotive working in Great Britain.** No. IV. — The mixed traffic 4-6-0s Part 1-2 *(to be continued).* (10 900 words & fig.)

1949 **621** .335 (81)
ıe Engineer, Nov. 11, p. 549.
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1949 **621** .33 (42)
ıe Engineer, Nov. 11, p. 560.
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ıe Engineer, Nov. 18, p. 576; Nov. 25, p. 620.
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ıe Engineer, Nov. 18, p. 582; Nov. 25, p. 611; Dec. 2, p. 635; Dec. 9, p. 667.
FREYSSINET (R.). — **Pre-stressed concrete** *(to be ntinued).* (4 000 words.)

Engineering. (London.)

1949 **621** .335 (42)
ıgineering, No. 4354, July 8, p. 46.
WAITE (H. G.). — Traction gearing. (2 500 words ıd fig.)

1949 **621** .431 .72 (42)
ıgineering, No. 4356, July 22, p. 91.
350 HP Diesel-Electric shunting locomotive. (1 500 ords & fig.)

1949 **691**
ıgineering, No. 4359, Aug. 12, p. 143; No. 4360, Aug. 19, p. 169; No. 4361, Aug. 26, p. 208.
STEWART (D. A.). — **Vibrated concrete.** (10 000 ords & fig.)

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ıgineering, No. 4362, Sept. 2, p. 235.
0-6-0 shunting locomotives for Western Region. (200 ords & fig.)

1949 **669**
ıgineering, No. 4363, Sept. 9, p. 267.
SILLARS (R. W.). — **New dielectric and semi-conıcting materials.** (2 400 words & fig.)

1949 **621** .134 .3 (42)
ıgineering, No. 4364, Sept. 16, p. 291.
Locomotive valve gear with independently variable ents. (500 words & fig.)

Modern Transport. (London.)

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odern Transport, Nov. 19, p. 15.
Coded track circuits. Use in continuous cab signalling. 000 words & fig.)

1949 **656** .211 .5 (42)
Modern Transport, Nov. 19, p. 17.
Left- luggage lockers. Coin-freed device for passengers. (500 words & fig.)

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Modern Transport, Nov. 26, p. 3.
MISSENDEN (E.). — **Railway motive power.** (2 000 words.)

1949 **385** (02 (42) & **625** .4 (42)
Modern Transport, Dec. 3, p. 8.
An underground instructional train. (1 500 words & fig.)

1949 **385** (42)
Modern Transport, Dec. 17, p. 3.
New tube railways for London. (1 200 words & map.)

1949 **621** .135 .1 (42)
Modern Transport, Dec. 17, p. 9.
Locomotive cab design. (1 000 words & fig.)

1949 **625** .232 (42)
Modern Transport, Dec. 17, p. 15.
Modern railway carriages. The Saloon at its Zenith *(to be continued).* (1 400 words & fig.)

1949 **656** .237 (42) & **656** .235 (42)
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Charges scheme merchandise traffic. (2 400 words & table.)

1949 **625** .25 (42) & **625** .4 (42)
Modern Transport, Dec. 24, p. 12; Dec. 31, p. 10.
New rolling stock for L. T. E. railways. (3 500 words & fig.)

1949 **625** .12 (42)
Modern Transport, Dec. 31, p. 5.
Securing track stability. Sand piles treatment of soft formation. (800 words & fig.)

1950 **621** .33 (42)
Modern Transport, Jan. 7, p. 3.
Liverpool and Southport electric lines. (1 500 words & fig.)

1950 **621** .131 .1
Modern Transport, Jan. 14, p. 5.
POULTNEY (E. C.). — **Notable locomotives 1910-1920.** (2 200 words & fig.)

1950 **625** .235 (42)
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Window glazing simplified. (800 words & fig.)

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POULTNEY (E. C.). — **Notable locomotives 1910-1920.** (550 words & fig.)

1950 **621** .33 (44)
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French electric traction experiment. (1 200 words & fig.)

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POULTNEY (E. C.). — **Locomotives of 1921-1930. — Part I.** (2 800 words & fig.)

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Electric traction across the Pennines. (2 000 words & fig.)

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U. P. receives **club and café-lounge cars.** (3 000 words table & fig.)

1949 **385** .3
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POULTNEY (E. C.). — **British Railways locomotive test plant.** (2 200 words & fig.)

1949 **621** .431 .72 (73)
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Electro-motive reports progress. (1 200 words & fig.)

1949 **656** .212 (73)
Railway Age, Nov. 5, p. 48; Nov. 12, p. 44.
Sante Fe revamps its largest freight yard. (4 800 words and fig.)

1949 **621** .138 .3 (73)
Railway Age, Nov. 12, p. 38.
Improvement of power. — Modernization of repair methods saves money on C. & N. W. (3 600 words & fig.)

1949 **625** .173 (73)
Railway Age, Nov. 26, p. 37.
Making manpower count with machines. (1 200 words & fig.)

1949 **621** .431 .72 (73) & **693** (73)
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Fire prevention on Diesel locomotives. (1 200 words.)

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Norfolk & Western installs twenty sleeping cars. (2 4
words & fig.)

1949 **656** .254 (7
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Coast Line installs train communication. (1 500 wor
& fig.)

1949 **625** .232 (7
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N. & W. re-equips « Powhatan Arrow ». (1 400 word

1949 **625** .2
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MORRIS (J. P.). — **Advantages of dynamic braki**
(1 500 words & diagr.)

Railway Engineering and Maintenance. (Chicago.)

1949 **625** .14 (
Railway Engineering and Maintenance, October, p. 9
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words & fig.)

1949 **625** .112 (
Railway Engineering and Maintenance, Novemb
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Electric device tells gage conditions. (600 words & fi

1949 **693** (
Railway Engineering and Maintenance, Novemb
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Methods and material for fire protection for bridg and trestles. (1 400 words.)

1949 **669**
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Methods of prevention and removal of corrosion fr steel structures. (1 200 words.)

Railway Gazette. (London.)

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Railway Gazette, No. 18, Oct. 28, p. 504.
Aluminium bridges at Sunderland. (1 800 words & fi

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Concrete standards for overhead railway electrificat in Holland. (900 words & fig.)

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Main-line electric locomotives for Brazil. (1 200 wo
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Double deck electric four-coach units. (800 words & fig.)

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Steel casting of locomotive components. (1 500 words & fig.)

1949 **625** .144 .1 (73)
Railway Gazette, No. 20, Nov. 11, p. 563.
Continuous rails in the Cascade tunnel. (500 words & fig.)

1949 **313** .385 (42)
Railway Gazette, No. 20, Nov. 11, p. 570.
British Transport Commission statistics. Four week period ended September 11. (300 words & tables.)

1949 **625** .231 (54)
Railway Gazette, No. 21, Nov. 18, p. 587.
All-metal third class carriage for India. (800 words & fig.)

1949 **621** .131 .3 (73)
Railway Gazette, No. 21, Nov. 18, p. 588.
POULTNEY (E. C.).— **Test of a C & O. 2-6-6-6 locomotive.** (1 800 words, tables & fig.)

1949 **625** .151 (42)
Railway Gazette, No. 21, Nov. 18, p. 591.
Manganese crossings at Newcastle. (400 words & fig.)

1949 **385** .(071 .3 (42) & **621** .33 (42)
Railway Gazette, No. 21, Nov. 18, p. 592.
Staff Instruction Train, London Transport. (900 words & fig.)

1949 **625** .1 (43) & **656** .25 (43)
Railway Gazette, No. 21, Nov. 18, p. 594.
Lateral removal of a complete signal box. (400 words & fig.)

1949 **656** .283 (42)
Railway Gazette, No. 21, Nov. 18, p. 598.
Ministry of Transport Accident Report. Glasgow Cross, Scottish Region, British Railways, January 31, 1949. (1 600 words & fig.)

1949 **656** .211 .5 (42)
Railway Gazette, No. 21, Nov. 18, p. 601.
Automatic luggage lockers. (300 words & fig.)

1949 **656** .283 (42)
Railway Gazette, No. 22, Nov. 25, p. 625.
Ministry of Transport Accident Report. Trowse, Norwich, Eastern Region, British Railways : February 3, 1949. (1 400 words & fig.)

1949 **621** .33 (42)
Railway Gazette, No. 23, Dec. 2, p. 643.
Power supply for Liverpool-Southport electric lines, L. M. R. (1 800 words & fig.)

In Danish. (= 439.81.)

Ingeniøren. (Copenhagen.)

1949 **625** .42 (493) = 439.81
Ingeniøren, No. 50, p. 1000.
BENDTSEN (P.). — The new **Junction line** at Brussels. (2 400 words & fig.)

Sikringsteknikeren. (Copenhagen.)

1950 **656** .257 (489) = 439.81
Sikringsteknikeren, No. 6 and 7, p. 413.
HANSEN (W.). — Some more data concerning the **safety installations** by means of relays. (3 900 words & fig.)

1950 **656** .25 (489) = 439.81
Sikringsteknikeren, No. 6 and 7, p. 420.
HANSEN (W.). — Data relating to the **safety technique.** (3 000 words & fig.)

In Italian.

L'Ingegnere. (Milano.)

1949 **721** .9
L'Ingegnere, ottobre, p. 1101.
NANNI (V.). — **Serbatoi in cemento armato** a base rettangolare. (4 000 parole & fig.)

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Ingegneria ferroviaria. (Roma.)

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ROBERT (G.). — Calcolo del **binario.** (10 000 parole & fig.)

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MERLINI (R.). — **Moderne istallazioni a tubi fluorescenti** realizzate in Francia e in Inghilterra. (5 000 parole & fig.)

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PLET (A.) & DEL GAIZO (L.). — **Connessione bimetallica per giunti di rotaie.** (2000 parole & fig.)

In Swedish. (= 439.71.)

Meddelanden från Svenska Lokaltrafik Föreningen. (Stockholm.)

1950 **625** .1 (493) = 439.7
Meddelanden från Svenska Lokaltrafik Föreningen, No. 1, p. 33.
HILLBONN (B.). — The construction of **the railway junction line** at Brussels. (1 200 words & fig.)

Nordisk Järnbanetidskrift. (Stockholm.)

1949 **656** .257 (489) = 439.81 = 439.82 = 439.71
Nordisk Järnbanetidskrift, No. 7, p. 177.
Safety installations with relays.
WESSEL-HANSEN. — Danish report. (5 100 words & fig.)
KLAVENESS. — Norwegian report. (600 wo & fig.)
KARSBERG. — Swedish report. (2 000 words & fi

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SVEAAS (H.). — **Electrification** on the Norwegi State Railways. (3 600 words & fig.)

1950 **621** .336 = 439. = 439. = 439.
Nordisk Järnbanetidskrift, No. 8, p. 234 and 248 a No. 9, p. 278.
Current contactor device. — Lectures at the Meeti of the « Nordiska Järnvägsmannasällskapet ». Ele trical Section.
ULLERFORS (K.). — Swedish report. (2 600 wor & fig.)
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Statsbaneingenjören. (Stockholm.)

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LUNDBERG (T.). — 1948 Report on **safety device** for level crossings. (1 500 words & fig.)

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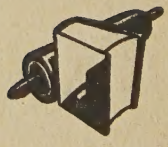

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